$p=\frac{F}{4\pi r}$, when F is equal to the number of dynes necessary to bring about detachment, r the radius of the wire and R the radius of the ring, it was found that as r varied from 0.0160 to 0.0405 centimeters, the value of p varied more than nine dynes and that it varied more than sixteen dynes as the value of $4\pi R$ varied from 4,120 to 11,808 centimeters. The technique introduced by Klopsteg,[4] though obviously correct, does not eliminate these variations, and corrections according to the correction factors of Cantor or MacDougall[5] are negligible in comparison. Variations in the case of benzene were quite as regular but not nearly as great.

McDougall[5] found that p diminishes as r increases. In the present experiments it is to be observed that p increases as either r or R increases. The data obtained with the ring supplied with the instrument apparently lie in that part of the curves where a change in the value of r or R produces an almost maximum effect. The writer can not offer a correction factor for obtaining correct surface tension values for the data obtained by the ring method, nor is it possible to review all the deductions given by Cantor and MacDougall for the ring method and of Lohnstein[6] and Lenard[7] for similar methods. Aside from any mathematical deduction, it is evident that the approximately correct values obtained for the surface tension of water with the ring supplied with the instrument are the result of the cancellation of equal and opposite errors. Values obtained for benzene with the same ring are too high.

It is claimed that only the ring method will give absolute values for the surface tension of colloidal solutions. Since the surface tension of many colloidal solutions changes with time and does not readily reach an equilibrium value, no method can be used for obtaining absolute values in the case of such solutions. In previous papers[8] it was shown by three methods, one of which was the ring method, that the surface tension of colloidal solutions changes with time according to the equation $\sigma = a/t^n$. Until more is known of the conditions under which the constant n changes it will be difficult to draw comparisons relative to definite periods of time and still more difficult to compare approximate conditions of equilibrium. Two hours can not be assumed as sufficient for reaching a state of even approximate equilibrium. Frequently the change following an initial period of two hours is several times as great as it was in this initial period. Some of the data given as typical for the ring method indicate that the change during a second period of two hours is nearly equal to that of the second half of the initial two hour period. It is therefore futile to try to obtain absolute surface tension values for many colloidal solutions. A definite time period should not be indiscriminately chosen as one in which even an approximate equilibrium point will be reached and the utmost discrimination must be exercised in comparing data which are relative to definite periods of time.

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[4] SCIENCE, 60 (1924), 319.

[5] SCIENCE, 62 (1925), 290.

[6] *Ziet. Physik. Chem.*, 10 (1892), 504.

[7] *Ann. Physik.*, 13 (1924), 385.

[8] *Jour. Phys. Chem.*, 29 (1925), 1137.

## SPECIAL ARTICLES

### BUTTERMILK AS A FERTILIZER FOR BLUEBERRIES[1]

IN casting about for acid, organic, nitrogenous fertilizers for blueberries and other acid-soil plants, I long ago considered buttermilk as one of the materials with which to experiment. My attention was again called to the subject last year by Herman E. Gasch, a Washington lawyer, farmer and man of understanding, who showed me a newly planted and thriving holly tree and told me, among other things, that he had given it a liberal application of buttermilk.

Plants in suitable condition for a buttermilk experiment became available in May of this year. They were blueberry seedlings that had been potted in January, 1926, in two-inch porous earthenware pots, in the standard soil mixture for the greenhouse culture of blueberries, rhododendrons and azaleas, two parts of upland peat and one part of sand. After about four months in a greenhouse maintained at a temperature of 55° Fahrenheit at night and 70° in the daytime, the growth of the plants had begun to slacken, as is normal under these conditions.

On May 14 a teaspoonful (about 5 cc) of buttermilk was applied to each of sixteen of these plants. Each pot contained about 50 cc of soil. These pots were plunged in sand in a flat containing thirty-nine other exactly similar, but untreated, plants.

Within ten days the leaves of the plants to which the buttermilk had been given had taken on a darker green color than those of the untreated plants. In two weeks the buttermilk plants were in active growth, some of them putting out new strong basal shoots, some branching from the upper axils, some pushing

[1] This early announcement of greenhouse experiments will, it is hoped, enable others to make similar fertilizer experiments out of doors with buttermilk or other byproducts of milk, on blueberries, rhododendrons, azaleas, and other acid-soil plants during the present season.

from a dormant bud, preparatory to a burst of new growth.

At the end of four weeks the plants fertilized with buttermilk were in the relative condition shown in Figure 1. They were 37 per cent. taller than the untreated ones, averaging 6.6 inches as contrasted with 4.8 inches.

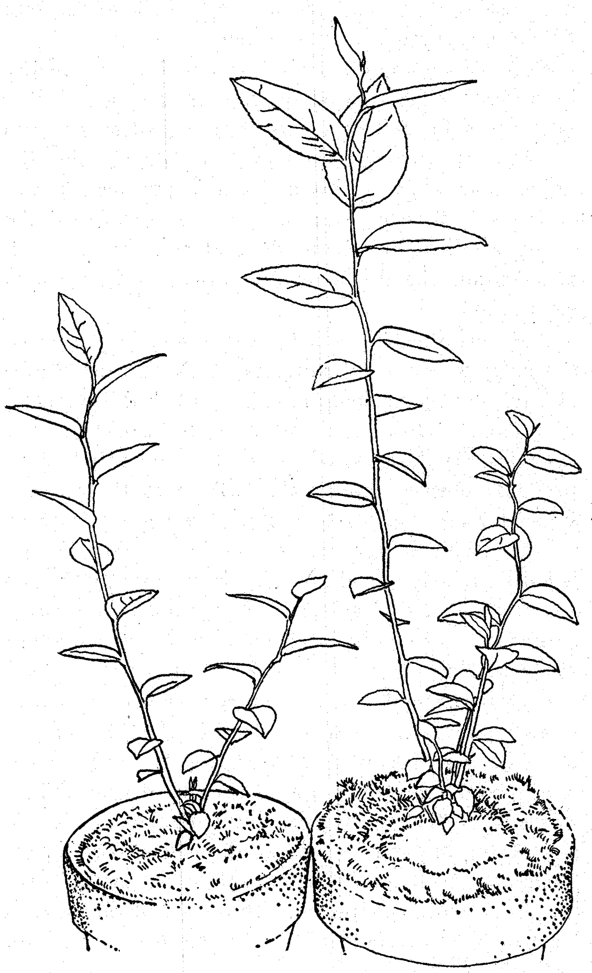

FIGURE 1. Buttermilk as a fertilizer. These two blueberry plants are in the same acid soil, which is well suited to them. The increased growth of the larger plant followed, in four weeks, the application of 5 cc of buttermilk.

The leaves on the new growth of the fertilized plants were conspicuously larger than those on the new growth of the plants not fertilized, and conspicuously larger also than the leaves on the old growth of both lots of plants. The area of the largest individual leaves as well as the total leaf area of the fertilized plants was more than double that of the others. The weighing of two plants, each selected as representing the average in its lot, indicated that the plants fertilized with buttermilk were, at the end of the first month, about three times as heavy as the others.

Another lot of sixteen plants in another flat was treated on the same date, May 14, with half a teaspoonful (about 2.5 cc) of buttermilk to each two-inch pot. These plants went through the same course of stimulated growth as those in the earlier experiment. At the end of the first month the plants treated with buttermilk were 32 per cent. taller than those not treated.

A third experiment, also begun on May 14, concerned the application of a teaspoonful of skimmed sweet milk to each of sixteen blueberry plants in two-inch pots. These plants were stimulated in substantially the same manner as those in the two buttermilk experiments. Indeed in the early days of stimulation the sweet-milk plants appeared to be growing a little more actively than the buttermilk plants. As a probable explanation of this earlier activity it should be stated that when buttermilk is applied to the soil the curd remains on the surface and after decomposition is washed into the soil in the process of watering. When skimmed sweet milk is applied to the soil it penetrates at once, leaving no residue on the surface, and presumably it turns sour within a few hours. The immediate penetration of the sweet milk and its consequent immediate contact with a larger part of the root system of the blueberry are believed to account for the somewhat earlier response of the plant to sweet milk than to buttermilk.

The acid peat-and-sand soil used in raising blueberry seedlings is an excellent medium for the support of acid-soil mosses. During the four months preceding the buttermilk experiments, the surface of the soil in each pot had become covered first with the protonema and later with the leafy plants of a moss which formed a ground cover of close, yellowish-green plush. When buttermilk was applied, the curd, saturated with whey, remained on top of the moss and killed all the moss plants with which it came in contact. The moss that was not killed, however, changed from yellowish-green to bright-green under the stimulating influence of the buttermilk and grew much faster than the moss in the untreated pots. The moss to which the skimmed sweet milk was applied was not injured by contact with the milk, and it took on the same bright-green color and active growth as the moss in the pots fertilized with buttermilk.

When the beneficial action of buttermilk on blueberry plants began to be evident from these experiments, an experiment was begun with azaleas. To each of twelve plants of a new and unnamed variety of kurume azalea, in four-inch pots, was applied a tablespoonful (20 cc) of buttermilk. The plants had been in the pots about five months and the leaves were somewhat yellowish-green. In about two weeks the azaleas to which the buttermilk had been applied had turned to a dark green color indicative of increased vigor.

No formal experiments were undertaken with buttermilk as a fertilizer for rhododendron seedlings, but to a single healthy bush of *Rhododendron maximum* five feet high and six feet broad, at my house, two quarts of sour milk was applied in May at the time when the leaves on new twigs were expanding. Although there were no similar untreated plants to be used as checks, there is an indication of beneficial effect in the fact that the new leaves grew within a month to a size distinctly larger than the leaves that were produced on the same plant in 1925 and in 1924 without this fertilizer.

To make certain which of the substances contained in milk act as fertilizer, additional experiments were made with these substances separately, namely, whey, casein and lactose (milk sugar).

In the first experiment with whey, begun on June 1, each of sixteen blueberry seedlings in two-inch pots was given a tablespoonful of this liquid, since this happened to be the amount of whey computed to contain the same amount of protein as a teaspoonful of buttermilk. The plants to which a tablespoonful of whey was applied suffered severely during the first five days, and at the end of two weeks they were still in worse condition than untreated plants. The amount of whey applied was so great that it penetrated to all parts of the root system of the plants and in a few cases some of the liquid ran out of the drainage hole in the bottom of the pot. The whey was very acid and it is almost certain that the injury to the plants was caused by this excess of acidity, for in another experiment, begun on June 5, in which half a teaspoonful of whey was applied to each of sixteen two-inch pots, there was no injury, the plants took on a darker green color at the end of a week, and in ten days they were growing more actively than untreated plants.

The experiments with whey have not continued for a sufficiently long period to show whether its fertilizing value is proportional to its nitrogen content, which is about one fourth that of buttermilk.

Whey applied as a fertilizer for blueberries or other acid-soil plants should be diluted with water, probably five to ten parts of water to one of whey. When sour milk or buttermilk that has become exceedingly acid from long fermentation is used as fertilizer it should be similarly diluted.

Casein applied in dry granular form on June 1, .22 gram, the amount in a teaspoonful of buttermilk, to each of sixteen blueberry plants in two-inch pots, began to produce a darker green color in the leaves in eight days. In ten days the casein-treated plants were clearly growing more actively than untreated plants. In two weeks fourteen of the plants had begun to branch or to make new growth from an uppermost dormant bud, both of these activities being evidence of a strong growth impulse not shown in any of the corresponding untreated plants. Up to the present time the experiments indicate that casein is the most active fertilizer of any of the derivatives of buttermilk used in these experiments.

The dry granular casein does not dissolve readily in water. When placed on top of the moss it lay partially solid for days, decomposing little by little after each successive watering, and drying out between times. In a second casein experiment begun on June 1, in which the moss was removed and the casein applied directly to the soil and covered with moist sand, the decomposition of the material was more rapid.

I am informed by Dr. L. A. Rogers, in charge of the dairy research laboratories of the United States Department of Agriculture, who furnished the casein, whey and lactose used in these experiments, that casein is the cheapest of the commercial nitrogenous products derived from milk, selling at the present time at about ten cents a pound wholesale, and at times having sold as low as five cents a pound. Whey is hardly a commercial material, being usually thrown away at cheese factories as unsalable. In many households sour milk and buttermilk are at times waste products.

Lactose, or milk sugar, was applied on June 1 to sixteen plants in two-inch pots, .25 gram, about one tenth of a teaspoonful, to each plant. The lactose was placed on top of the moss and dissolved and washed into the soil by spraying with water. At the end of ten days and again at the end of two weeks the plants thus treated appeared to be not quite so healthy as those not treated. In several of the lactose-treated plants a reddening of stem bases and leaf stalks had taken place.

Thinking that a substance as oily as cream might perhaps be injurious to blueberry plants I applied a teaspoonful of it on May 14 to the soil of each of eight plants in two-inch pots. These plants showed neither injury nor stimulation as a result of the application.

It is clear from these experiments that while skimmed milk, buttermilk, casein and whey are useful as fertilizers for blueberry plants, cream and sugar are not. These are still best utilized, in accordance with established practice, at breakfast, on the blueberries themselves fresh from the icebox.

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