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The process of fertilizing water is essentially an attempt to increase the production of aquatic plants and animals, just as the fertilizing of land is an attempt to increase the yield of plant crops and ultimately the animal stock. The first step in each process is to provide more suitable conditions for a larger plant growth, which, in large part, may be accomplished by augmenting the supply of nutrient materials necessary for growth. In water the plant growth most quickly stimulated is the free-floating, and often very minute, algae, which provide forage for small aquatic animals, which in their turn are food for fish.

A great deal has been done upon the nutritional requirements of plants. Although the stress has been upon the higher plants, yet considerable has been accomplished in the field of algology. Pringsheim (1924) presents several formulae used by various workers for the pure culturing of many species of algae. All these formulae agree in possessing the following elements: nitrogen, phosphorus, calcium, potassium and traces of iron. Several writers deem it necessary that magnesium be present in minute quantities. Silicon is essential for the growth of diatoms. Strom (1933) indicates that for some algae, as Coccymyxa simplex, manganese has the same butritive value as iron, but for others, as Scenedesmus obliquus, the sutstitution cannot be made.

Without doubt algae have been pure cultured in such media as presented by Pringsheim, but in many cases efforts have been attended by little success. The results of Allen and Nelson (1910) are illustrative. They observed that in culturing marine diatoms in synthetic sea water minute traces of some substance, or substances, present in the natural sea water, but not in the synthetic were necessary for a good growth. Bottomley (1914, 1917, 1920), experimenting chiefly with Lemna, concluded that there existed growth-promoting substances necessary for the growth of chlorophyllaceous plants and these were similar in nature to vitamins, for which substances he proposed the same "auximones". Later Clark and Roller (1924, 1931) and Clark (1926) showed that these substances, derived from organic materials, were not vitamin in character, i.e. they were not essential for the growth of green plants. They were, however, decidedly growth-promoting in action.

It is agreed that the addition of inorganic fertilizers increases the productivity of the treated waters. Yet, among European workers in particular, there is a decided difference of opinion as to what elements should be added to water in order to obtain the best result. In their experiments they have stressed the use of three elements, nitrogen, phosphorus and potassium, which, when used together, constitute a "complete fertilizing" (Volldungung). Even with a "complete fertilizing" with inorganic salts the results have frequently left much to be desired.

In our work upon the fertilizing of fresh water, herring meal has been principally used as the fertilizer. In two experiments the production of algae in water fertilized with 0.25, 0.75 and 1.25 gm. of herring meal per litre has been contrasted with that in water fertilized with the amount of nitrate and phosphate which would theoretically be liberated into the water upon the complete decomposition of the above concentrations of herring meal, provided all the nitrogen and phosphorus indicated by the analysis of the herring meal became available as these salts. The inorganic salts employed were potassium nitrate and potassium dihydrogen phosphate - a "complete fertilizing." It was calculated that a fertilizing with 0.25 gm. of herring meal per litre corresponded to 24.95 mgm. of nitrogen (N) and 13.60 mgm. of phosphate (PO) per litre. The experiments were carried out in flower pots with 12 litres of water in each.

In one experiment (Experiment A8), tap water was inoculated with a culture containing two algae and one ciliate, so that the initial numbers per litre in the pots were as follows: Chlamydesmus single, 3,303,000; Scenedesmus colonies, 4,157,000; Scenedesmus single, 3,079,000; Chilodon, 98,000. A control without fertilizing materials was provided. The experiment ran for two weeks, from August 30 to September 13, 1933. Samples were taken at the end of the first and second weeks. The temperature of the water ranged widely during the period of the experiment from 9.1 to 27.1°C. (average 17.6°C.). However, the difference in temperature between the pots at any one time was never greater than 2.0°C., and usually less.

In the other experiment (Experiment A6), the water, with the contained phyto- and zooplankton, was taken from an unfertilized earthen pond, and the initial number of plants and animals per litre was: Chlamydomonas, 85,000; Scenedesmus colonies, 48,000; Ankistrodesmus, 1,500; Chlorella-like species, 850,000; diatoms, 3,500; Cosmarium, 500; Closterium, 137; Philodina citrina, 13;

Daphnia pulex, 48; Chydorus sphaericus, 12; Cypridopsis vidua, 4. The time of the experiment extended from August 11 to 22, 1933, during which time the temperature of the water in the pots ranged from 15.8 to 29.3°C. (average, 21.6°C.).

In Experiment A8 the inorganic salts, apparently through a more ready availibility, caused a greater production of algae during the first days. However, nutrient materials were liberated quite quickly from the decomposing herring meal, for after one week the total yield of algae in the water fertilized with 0.25 gm. of herring meal per litre was 353 millions of algae per litre as compared to 119 millions per litre with the corresponding amounts of nitrates and phosphates. With 0.75 and 1.25 gm. per litre the aggregate yield over the same period was somewhat less in the organically fertilized water. Yet the difference was small. After two weeks the production in the water with herring meal was much larger than in that with nitrate and phosphate. This was particularly the case with a concentration 0.75 gm. per litre. A comparison of the yield of algae in numbers per litre between the two types of fertilizing is shown in figure 1.

In the second experiment with mixed plant and animal plankton the yield of Chlamydomonas, Scenedesmus and Chlorella-like species was decidedly less after 11 days in the water which had been fertilized with nitrate and phosphate than with herring meal. The total yield of algae in the water with 0.25 gm. of herring meal per litre was 23 times that in the water with the corresponding concentration of salts; with 0.75 gm. per litre it was 206 times, and with 1.25 gm. per litre, 182 times, (figure 2).

The number of zooplankton in the respective pots is given in table 1. While Daphnia pulex and Chydorus sphaericus would apparently survive only in a concentration of 0.25 gm. of herring meal per litre, they were present in all concentrations of the salts, although, in the case of Daphnia, there were indications that the highest concentration of these was not very suitable. With 0.25 gm. of meal per litre there were 193 Daphnia per litre as compared to 119 with the nitrate and phosphate. Although the action upon the zooplankton was not so contrasting, perhaps due to the short period of the experiment.

The results of these experiments show definitely that the addition of an organic substance, such as herring meal, has a greater stimulating action upon the growth of algae than a comparable, in these cases perhaps more than comparable, amount of nitrate and phosphate. Wiebe (1930) found that organic fertilizers, soy bean meal and shrimp bran, gave better results than superphosphate. He says (p.170): "It may be that the soy bean meal and shrimp bran contain along with nitrogen some other substances that make a greater utilization of the nitrogen possible" (italics ours). Clark and Roller (1931,,p.299) point out that "the value of farmyard manure has been generally recognized to be greater than the value of the content of the chief elements in fertilizers." The indications are, therefore, that a "complete fertilizing" with potassium, nitrate and phosphate does not supply to the water all the elements essential for the best algal growth. These elements may be small quantities of iron, magnesium, etc., or certain growth-promoting substances such as indicated by Bottomley and Clark and Roller.

In natural waters one might suppose that these various substances were present already, and in sufficient amount, as it has been shown that minute quantities are all that are required. The increased productivity in water after the addition of mineral fertilizers tends to substantiate this view to some extent, but judging from our results, and those of others, fertilizing augments the supply of these substances, or introduces new ones. Thus the conclusion would seem to be that an organic fertilizing is more desirable for algal growth than a comparable mineral treatment.

TABLE 1. Number of zooplankton produced in organically and inorganically fertilized water. Number per litre. (Experiment A6).

Fertilizer	Daphnia pulex	Chydorus sphaericus	Cypridopsia vidua	Chironomid larvae	Cilitates
Meal (0.25 gm. l.)	193	7	2	292	153,000
" (0.75 gm. l.)	0	0	0	69	--
" (1.25 gm. l.)	0	0	0	38	307,000
Salts 0.25 gm. meal l.	119	4	3	303	127,000
" 0.75 gm. meal l.	149	3	0	89	51,000
" 1.25 gm. meal l.	6	3	1	35	0

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