

The Manufacture and Properties of Liquid Seaweed Extracts

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ABSTRACT

Liquid seaweed products were introduced in 1950 and now enjoy a world-wide reputation. The manurial value of these products is not related to their N. P. K. content and they show unusual properties such as enhanced germination of seeds, increased frost resistance and they induce resistance to fungal and insect pests.

The relevant literature is reviewed together with supporting evidence from other sources. The manufacture and use of these products is discussed.

Iii my first contacts with (the late) Tony Stephenson, I discounted many of the claims he made for «Maxicrop» and I was surprised when a second product, «Baby Bio», was launched on the British Market. A demand for these products was soon apparent; one to the retail market and the other in commercial horticulture. The story of this unusual venture has now been published in a book (STEPHENSON, 1968) which outlines the manufacture and uses of these extracts.

By 1958, export sales began to develop and Tony and I discussed ways of producing a dried extract for the export market and the type of publicity and research needed to foster further development. As a matter of fact, the first dried seaweed extract was exported early in 1959.

At this time, the use of seaweed fertilizers was unorthodox and several factors contributed to my deviation from the tradional views of soil chemistry. The first was an analysis of my soil which was found to give unusually high figures for potash and «available» phosphorus.

* This contribution contains the substance of one of the special lectures at the Symposium.

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This caused some surprise because it had been liberally treated with seaweed for seven years and completely neglected for the previous thirty years; seaweed would supply the potash but it is a poor source of phosphate. Moreover the soil is an alkaline shell-sand (pH 7.4) which usually leads to low «availability» of the phosphate. Nevertheless, the analytical result was confirmed but my doubts remained. However, early in 1959, DUFF and WBBLBY (1959) showed that 2 ketogluconic acid, an exometabolite of common soil bacteria, could release phosphate from insoluble phosphatic minerals and would also chelate calcium to yield «available» phosphate. This work gave a reasonable explanation of the analysis of my soil but it also raised doubts in my mind about conventional ideas on soil nutrition. These doubts were increased when BIRCH (1959) showed that wetting and drying a soil sample increased the nitrogen content by as much as the equivalent of 1 ton of ammonium sulphate per acre, which is about 5 times as much as is ever used on arable soils. (In due course, this caused the analysis of soil nitrogen to be discontinued.)

Both these papers appeared in the early months of 1959 and they strained my belief in the orthodox views of soil chemistry and caused me to study the subject. I soon found that chemical methods of soil analysis were chosen for their apparent simplicity and ease of operation; they appear to have few other virtues! In this roundabout way, I started with doubts about the value of seaweed extracts and reached greater doubts about soil science in general. The fact remains that soil science is a complex and little understood subject which is over-simplified to meet day-to-day demands.

At this stage, I had several tasks to perform. Firstly, I had to help the industry and, with this in mind, I started to survey the literature. At first sight, many of the claims made for seaweed are simply incredible but it soon became evident that equally unusual claims are made for other substances, many of which are known to be in seaweed extracts. This data was presented at the last Symposium (BOOTH, 1966).

It is important to remember that seaweed extracts are applied as foliar sprays and this was contrary to all concepts of plant nutrition when they were introduced in 1950. At that time, agricultural dogma demanded that all nutrients entered the plant through the roots and the function of the leaf was confined to photosynthesis. Yet during the next decade the work of Tukey, Wittwer and their associates proved that foliar feeding was effective and, even more revolutionary, was their demonstration that nutrients are actually leached from the leaf by rain. Foliar feeding became orthodox practice in the 1960's; this notable change helped the sale of liquid seaweed products.

Work in this field was reviewed recently by FRANKE (1967) and only a few points need mention. Firstly, absorption is best early in the day,

after the dew has evaporated, and becomes negligible in the dark. Absorption is rapid in the first hour (primary uptake) and then ceases and is resumed later (secondary uptake); the interval between these two stages usually exceeds 2 hours and the secondary uptake often occurs 1-2 hours before sunset. Most elements are absorbed and absorption is enhanced by urea, sugars and the bicarbonate ion. This effect of sugars is noteworthy because they are present in varying amounts in seaweed extracts. The leaf absorbs sugars rapidly and they appear particularly beneficial to fruit trees after blossom set when there is a sudden migration of sugars from the leaf to the rapidly growing fruit (Eep. E. Mailing Ees. Sta. for 1966).

This trend to foliar-feeding was enhanced by OLAND'S work (1963) on the beneficial effects to apples of post-harvest urea sprays and the subsequent demonstration, two years later, that this late application of urea was an effective means of controlling scab on the next season's fruit (BURCHILL *et al.*, 1965). This, incidentally, is a unique example of the control of plant disease by a fertilizer.

These events started the use of foliar sprays and seaweed extracts must benefit from this change. My own view is that seaweed extracts with added nitrogen and potash have a potentially large horticultural market. The U. K. crop of tomatoes, for instance, uses annually 3000 tons of urea and 8000 tons of potassium nitrate; the glasshouse crop in the Netherlands (12,000 acres) is double that of the U. K. Most of the fertilizer used in greenhouses is applied in solution. The change to fertilizers on outdoor crops is also evident, as is the increased area under irrigation; it is obvious that irrigation and foliar feeding can be combined to give another large market for soluble fertilizers. The seaweed firms must consider these potential outlets for fortified seaweed extracts.

Seaweed fertilizers supply trace elements and are particularly useful on alkaline soils where deficiency diseases are common. The metals in the extracts are chelated and it is possible to chelate added metals in the manufacturing process (Maxicrop, B. P.). Products with enhanced iron and/or magnesium content are available and other metals can be incorporated as required. The main outlet for these chelates is to counteract lime-induced chlorosis in orchards on chalk soils where 10-12 gallons per acre, applied in 4-6 doses in May-June, has given excellent results.

Research on seaweed fertilizers is thinly spread over a large number of journals and work sponsored by the manufacturers is rarely published through the usual channels. Since the sale of seaweed products is the basic reason for fostering most of this work, it is unfortunate that the results are rarely published. There is also a need to associate seaweed with orthodox practice and the situation was admirably reviewed by

Professor FOGG (1967) when he wrote that the results with seaweed «may savour a little of "muck and magic" but seem definite and worth further investigation)). The image of seaweed fertilizers would be improved by publication of the results in one of the more widely read journals.

Growth promoting substances in seaweeds are well known but some recent papers merit attention. GUPTA (1967) showed that rice seeds germinated more readily when soaked in extracts of *Phormidium foveolarum*, a blue green alga which does not fix nitrogen. Similarly, extracts of *Fucus vesiculosus* and *Furcellaria fastigiata* were shown to be effective growth promoters (DAGYS et al., 1963). In both papers, aqueous extracts proved more effective than alcohol extracts. Two papers by SCHIEWEE (1965, 1967) extend the range of seaweeds which contain indole compounds and comment that alkaline hydrolysis released large amounts of auxin; this point will be referred to later. Gibberellins, probably A2 or A3 and A7, are now known in *Hypnea musciformis* (JENKINS and MCCOMB, 1967) but the most important paper on gibberellin (ARNOLD et al., 1967) shows an unusual increase in crop yield when sprayed on pasture at the end of the growing season. Spraying at the low rate of 4 g/acre gave an additional yield of 500 lb/dry matter/acre and a synergistic effect was given with the synthetic auxin, α -naphthylacetic acid. Larger amounts of gibberellin (up to 105 g/acre), however, were less effective. The Australian authors suggest that this small quantity of gibberellin can extend the grazing season by a month or more.

The main interest in growth controlling compounds is now centred on kinetin and similar compounds; the properties of these substances was recently reviewed by LETHAM (1967). The kinins possess many properties which have been claimed for seaweed extracts e. g. they enable plants to resist disease and unfavourable temperature conditions, they will induce fruit set, and, above all, their ability to retard senescence is an outstanding and unusual property. Kinetin has not yet been isolated from the larger seaweeds but the presence of kinin-activity in two unicellular marine algae was demonstrated earlier this year (BENTLEY-MOWAT & EEID, 1968). Kinins are now known to be present in a wide variety of plants (ca. 50) and it seems probable that they are present in seaweeds. In fact, some of the results recorded below on the effect of seaweed in delaying senescence suggest kinin-activity in seaweed extracts. In this respect, it is interesting to note that varietal differences in the keeping quality of Brussels sprouts have been correlated with their kinin content (THOMAS, 1968); extracts of the variety Avoncross contain more kinin than those from Jadcross which does not keep as well.

Two other substances which are present in seaweed have been shown to exhibit growth-promoting properties. Mannitol has been shown to

stimulate root growth in *Agrostis alba* (JACKSON, 1965) and phenolic substances also initiate root development and exhibit growth-promoting properties (POAPST & DUNKEE, 1967; CRAIGIE, 1965). The seaweed *Ascophyllum nodosum*, which is widely used in the manufacture of seaweed extracts, is particularly rich in phenols. A predisposition of the phenols to oxidation in alkaline conditions, which is characteristic of those in *A. nodosum*, appears to enhance the property to develop root-initiation (POAPST & DUNKEE, 1967).

Mr. Blunden published a paper earlier this year (BLUNDEN et al., 1968) in which he showed that extracts of various seaweeds considerably increased nutrient uptake but I will not enlarge on this topic because he will discuss it later this week. Our research station at Long Ashton investigated the effect of a very dilute solution of «Maxicrop» (1/450) on blackcurrants following claims by growers that it reduced damage from sulphur sprays; even at this high dilution, yields were improved but the results were not statistically significant (SMITH & CLARKE, 1967).

A field trial in New Zealand assessed the effects of «Maxicrop» and eight synthetic insecticides against red spider mite on apples (Sturmer and Delicious) and reported unfavourably on the seaweed extract and two of the synthetic products (SLADE, 1966-1967); it was, however, recorded that «Maxicrop» halved the mite population which substantiates other observations (STEPHENSON, 1968; BOOTH, 1966). It is now well known that substances with growth-regulating properties also have an inhibiting effect on disease and insect pests; this generalisation is applicable to natural and synthetic auxins, gibberellins, kinins and to synthetic growth-retardants such as OCC and B-9. Since seaweed extracts contain growth promoting substances it now seems logical that they should also inhibit the growth of insect pests and fungal diseases.

Claims that seaweed extracts delay storage rots have been reported for two different products and suggest kinin-like activity. SENN and SKELTON used «Sea Born» (= «Maxicrop») on peaches and report positive results and a varietal difference in the degree of response. Provolny used an extract manufactured by Algea Produkter on cucumbers and reported a big yield increase (42 %) and greatly reduced storage losses (PROVOLNY, 1966).

Since the last Symposium, two patents have been published on the use of alginates to assist germination and prevent erosion under unusual conditions such as exist on the verges of motorways. One uses an alginate solution (TRUAX) and the other (KURTH) makes various claims for condensates of alginic acid with formaldehyde or hexahydric alcohols.

The recent redevelopement of seaweed research in Chile has given three very interesting papers on the effect of seaweed on calcareous soils (LUTTINGER, 1967; AXT MERCHANT, 1966; OPPERMANNS CASTILLO, 1966). The first paper showed that additions of seaweed significantly

increased both the «available» potash and nitrogen in the soil. The second paper used additions of seaweed to incubated soil samples and demonstrated an increase in «available» phosphate. These experiments also showed that small additions of seaweed (0.38 %) produced more «available» phosphate than larger additions (1 %) and concluded that the effect was due to microbial action stimulated by the seaweed ; this result recalls my own experience with a similar soil in 1958. It may be added that similar results are obtained with farmyard manure and the latest work on this topic (SALTER & WILLIAMS, 1968) makes the observation that «... over the period of the experiment large increases in exchangeable phosphorus and potassium were obtained on plots which had received farmyard manures. The better effect from small quantities of seaweed recalls some earlier work by SENN *et al.*, who found 250 lb/acre gave better results than 500 lb/acre ; similar results are common with seaweed extracts where a dilution of 1/200¹ or 1/300 is usually more effective than more concentrated sprays. The third paper from Chile describes the effect of the brown seaweed *Macrocystis integrifolia* on the availability of iron in a calcareous soil and used soil samples incubated with seaweed, ferrous sulphate or alginic acid. The mixture of soil and seaweed gave the highest level of «available» iron, alginic acid was less effective and the addition of ferrous sulphate was ineffective. Calcareous soils present unusual «availability» problems and these effects on the «availability* of iron and phosphorus are worth further study.

Seaweed usually grows in remote areas and has to be transported to the market; this was recognised 112 years ago in the first patent for a seaweed manure (GARDISSAL) and was again mentioned in the first patent (1912) for a liquid seaweed extract (PENKALS) ; incidentally this method used extraction under alkaline conditions. The first commercial extract, «Maxicrop», used an alkaline extraction process (MILTON). «Biomisation Fluids (now well-known as «Baby Bio») and «Biohumus» were marketed shortly afterwards and were made by aqueous extraction of seaweed and peat. Other products became available in the 1960's e. g. «Marinure», «Sea Born», «Seahorse», «SM-3», «Trident» and a product made by Algea Produkter A/S. These extracts may be made by simple extraction or high pressure alkaline extraction of the seaweed, usually *Ascophyllum nodosum*.

The alkaline extraction process is described in the original patent (MILTON) and in Mr. STEPHENSON'S book (1968) ; it was also discussed by Dr. Milton at the 1961 Symposium (MILTON) who stressed that chelation prevented loss of metals in the faintly alkaline extract. This process gives a very high yield and over 90 % of the raw material can be accounted for in the product; about 5 % is lost on filtration. This method extracts plant hormones not extracted by milder conditions,

e. g. SCHIEWER (1967) states that increased amounts of auxin are released by alkaline hydrolysis and BENTLEY points out that the auxins, to some extent at least, are present as insoluble complexes. In fact, BENTLEY (1960) recommends alkaline hydrolysis (*N*- NaOH) under slight pressure to extract auxins not previously extracted by milder methods.

The main objections to this method are the cost of the equipment and the need to circumnavigate a patent; these factors led to the manufacture of seaweed extracts by alternative methods. Naturally, the water soluble constituents in seaweed varies between species and also with the time of the year when the seaweed was harvested but, on average, about 30-40 % of the dry matter is readily extracted with water. The extraction may be carried out in neutral, acid or alkaline conditions but I prefer slightly acid solutions (0.01 *N*- HCl). Under these conditions, extraction is rapid and independent of temperature, i. e. in a typical experiment, a liquor of D. 1.04 (ca. 8 % solids) was given by 10 minutes extraction at 20°C but the density of the extract only rose to 1.041 after 2 hours at 60°C. Acid solutions filter more readily than neutral extracts but, if a metal filterpress is used, a readily filtered solution can be obtained by neutralization with lime. The filter cake retains about 25 % of the soluble solids which can be recovered by washing on the press and using the wash liquor in a subsequent extraction ; alternatively, a two-stage extraction process can be used. Either method will give an extract with a solid content around 12 % which may be further concentrated by conventional methods or standardised to a fixed total solids, usually in the region of 8-10 %..

All seaweed extracts are liable to ferment on standing and preservation with formaldehyde (1 :1000) is usual. There is some difference of opinion on the most desirable pH of the finished product but there is little evidence to support any particular figure ; I prefer a slightly alkaline product, pH 7.2-7.4, simply because most physiological fluids fall into this range.

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