SODIUM AS AN ESSENTIAL MICRONUTRIENT ELEMENT FOR HIGHER PLANTS

Thesis submitted for the Degree of Doctor of Philosophy

by

P. F. Brownell

May, 1958.

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PART 1 INTRODUCTION

The need for the macronutrients, calcium, potassium, magnesium, nitrogen, phosphorus, and sulphur, has been obvious for a long time. Sachs included them all in his culture solution of 1860, as well as the micronutrient, iron, which had been known as essential since 1844 (Bonner and Galston 1952).

During this century, when the salts used in culture solutions had been carefully purified, the discovery of other elements required in trace amounts was made. Previously, these elements had been present as impurities of the salts of culture solutions in amounts large enough to satisfy the plants' requirements.

When this research was initiated, the elements sodium and chlorine had not been shown to be essential for the growth of higher plants, possibly due to their universal presence in at least trace amounts wherever plants grow under natural conditions.

It has been shown that varying amounts of sodium and chlorine are contributed by atmospheric accessions of salt to plants and soils under field conditions (Hutton 1953; Turton 1953; Downes 1954). These elements may be redistributed in the soil by the movement of water (Jackson <u>et al.</u> 1956), or by their uptake into the roots of plants with subsequent re-deposition in falling leaves and debris.

When there is little drainage, as in arid areas, or where there is an impeded water-table, salt may accumulate in concentrations in the soil which hinder or prevent plant growth. On the other hand, where drainage is rapid, much of the sodium and chlorine pass below the reach of the root systems, so that only traces of their ions remain within the root zone. Although the effects of excessive salt concentrations have been studied widely, little is known of the possible roles of these elements in plant nutrition. No experiments had been reported in which plants had been grown in media really low in sodium and chlorine when this study began. It therefore seemed possible that if these elements are essential for growth, they must be needed in very small amounts indeed. The chief object of this work is an attempt to determine whether there was any evidence for this possibility by studying the effects of small amounts of sodium and chlorine on plants cultures under conditions from which these elements had been carefully eliminated.

The effects of chlorine on the photochemical activity of isolated chloroplasts and on the growth of the intact plant have been studied. Warburg and Luttgens, according to Arnon (1951), suggested that chlorine might act as a coenzyme in the Hill reaction of photosynthesis. Arnon and Whatley (1949), however, grew sugar beet and chard in nutrient solutions "without chlorine" and obtained excellent growth. They isolated chloroplasts from these plants and found that they showed only weak photochemical activity, but, as Warburg and Luttgens had found, they were reactivated on the addition of chlorine. They concluded that chlorine was not required for the activity of chloroplasts <u>in vivo</u>, but that it was necessary in isolated chloroplasts to protect some essential photosynthetic factor which was otherwise irreversibly destroyed in the light.

Lipman (1938), Eaton (1942), and Raleigh (1948) have described experiments in which small applications of chlorine-containing salts increased plant growth in water culture, but it was not until late in 1954, during the progress of this work, that Broyer <u>et al</u>. showed decisively, that chlorine is an essential micronutrient element for several species. To accomplish this, they used highly purified salts, and grew plants in a greenhouse in which the air had been cleaned by passing it through activated charcoal.

These results were confirmed in later experiments by Ulrich and Ohki (1956), Ozanne, Woolley, and Broyer (1957), and Johnson et al. (1957).

Sodium has been shown to be an essential element only for the blue-green alga, Anabaena cylindrica, by Allen and Arnon (1955). The alga was grown in Petri dishes, the nutrient salts were purified by recrystallisation, and glass-distilled water was used in the growth experiments in which "optimal growth" was obtained when the sodium concentration of the culture media was 5 p.p.m. or higher. Lithium, potassium, rubidium, or caesium were not able to replace the alga's sodium requirement. The effects of sodium on higher plants, however, appear more complicated. In many past observations, the dry weight production of plants growing in the field or in soil culture has increased following the application of salts of sodium. The literature dealing with such observations has been adequately reviewed by Harmer and Benne (1945), Lehr (1953), and Wybenga (1957). Although the results of these investigations are of possible economic significance, they are outside the scope of this work, as they give little information on the actual role of sodium in plant nutrition. Such increases in yield could have been due to the effects of the salt in either modifying the soil, or in increasing the uptake of other ions, or to the anion associated with the sodium being involved in the nutrition of the plant.

It has been shown that increase in dry weight occurs following the application of salts of sodium to various higher plants growing in low-potassium culture solutions (Richards 1944). This seems to indicate that sodium may partially replace the function of potassium in some species. There are also suggestions in the literature that the dry weight of some plants, mostly members of Chenopodiaceae, increases in solutions containing adequate potassium following the application of sodium (Harmer et al. 1953; Lehr 1949). This latter evidence, confused as it is, suggests that sodium may have an independent role as a nutrient element. This thesis presents a series of experiments designed to clarify this problem.

The description of this investigation is in 5 parts. The methods used to obtain sodium and/or chlorine-free culture conditions, and the analytical techniques used throughout the study are given in Part 2. In Parts 3 and 4, a series of experiments are described from which evidence was obtained that sodium is an essential element for the bladder saltbush, Atriplex vesicaria Heward ex Benth. This species occupies large areas of arid Australia, and was chosen for investigation as it accumulates large quantities of sodium chloride in its leaves (Wood 1925).

Part 5 describes a series of preliminary experiments in which the effects of sodium on other species were examined.

Experiments described in Part 3 were carried out in an ordinary glass-house, but the experiments described in Parts 4 and 5 were conducted in a pressurised greenhouse.

In this thesis, the chief objective has been to show the development of the subject rather than to present an account immediately suitable for publication.