MICRO-ELEMENT NUTRITION OF PLANTS

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PREFACE

An attempt is made in this book to present a comparative account of the effects of several micro-elements on various aspects of the physiology of economic plants. The subject matter has been arranged in such a sequence that it may be helpful both to the research workers in the university and to the agricultural scientists interested in solving practical problems of crop production and plant nutrition under field conditions. Relevant facts from over one thousand contributions of different workers, have been marshalled together in this comprehensive review on the Micro-element Nutrition of Plants. Our thanks are specially due to Dr. J. N. Tandon, M.Sc., Ph.D., for the help received in the correction of the proof and in the compilation of authors' index and subject index. We are also indebted to the National Institute of Sciences, India, for the financial help received in connection with the scheme on micro-element nutrition of sugarcane and for the grant of a fellowship to the junior author, which greatly helped in completing this book.

Banaras Hindu University,
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CHAPTER I

MICRO-ELEMENTS OF PLANT NUTRITION

Introduction

Eversince the researches of Woodward (1), Tollens (2), Sachs (3), Knop (4), Schimper (5), Pfeffer (6), Crone (7), Tottingham (8), Shive (9), and Hoagland (10), the science of plant nutrition has been put on a more rational basis for investigating the relation between inorganic nutrients and plant growth. Micro-elements are now known to stimulate various physiological activities when presented in infinitesimally small quantities (11, 12, 13). They play an important part in animal nutrition and disease prevention (14, 15, 16, 17), regulate the physiology of the fungi (18), serve as catalysts in fermentation processes (19), and stimulate growth of higher plants (20, 21), with many and varied types of responses (22). Their importance in agricultural and agro-biological problems has been widely recognised (23, 24, 25, 26, 27, 28, 29, 30, 31). Boron undoubtedly belongs to this class (32-41). Its occurrence in plants is fairly widespread, yet traces of boron are helpful in growth and metabolism of plants (42). It is claimed to behave as an ampholyte (43). Seeds usually contain small quantities of this element (44) but this supply is seldom commensurate with the requirement for normal growth (45). This has been conclusively proved in plants of different habitat and growth behaviour with the result that boron deficiency is now known to cause widespread physiological diseases (46).

Manganese is equally essential for growth of seedlings (47) and metabolism of all higher plants (21). As a micro-element it regulates development and growth (42, 48) and is not easily replaced by any other inorganic nutrient (49). Quality and yield are improved in presence of this element (47). Its absence causes deformities in tissue formation while general growth and metabolism are adversely affected. Copper is another micro-nutrient taking important part in all oxidation-reduction reactions (43). Its biological essentiality is related to its atomic structure (50). It is helpful in preventing diseases but its utility in better crop production on a field scale is not well recognised. Zinc is also essential for some fungi and higher plants (51-55). It regulates growth, elongation, auxin concentration (56) and oxidation-reduction reactions in plants (43). Its requirement, however, is so low that in nature sufficient quantities of zinc are considered to be available in many soils. Yet instances are not uncommon to indicate efficient growth and quality of plants in response to this element (57, 58). Molybdenum belongs to a group of elements of unknown function in plant nutrition (43). It affects growth and leaf colour (21, 59). Response of this nutrient varies with soil, crop, season and climatic condition with inconsistent results (60). Occasionally, it is poisonous to plants and animals causing varied types of diseases.

Other elements of plant nutrition which are found helpful only in small concentrations, include iron (3, 61-69), aluminium (70), silicon (71-76, 256), arsenic (77-85, 257, 258), selenium (86-97), chlorine (98-102), fluorine (103-106), bromine (107), iodine (108-114), cobalt (115-120), nickel (121, 122), uranium (123), thallium (67, 124, 125), palladium, berryllium and zirconium (123, 127), rubidium (126-129), barium and lithium (130, 131, 132), strontium and chromium (133, 134), cadmium (134, 135), mercury (136-146), thorium (147), vanadium (148, 149, 150), caesium (126, 128), gallium (151-154), lead (155), plutanium (156), radium (157), scandium (158), silver (159), tellurium (160), titanium (161, 162, 163), and tungsten (135). With increasing knowledge of micro-element responses, new elements are being added to the list of micro-elements. Their universal essentiality is, however, considered to be of doubtful significance. A critical discussion of the responses of these micro-elements appears elsewhere (17, 26, 27). For a comprehensive bibliography of researches on micro-elements, reference may be made to other contributions (164-177). For a review of non-parasitic diseases caused by deficiencies of copper, zinc, manganese and boron reference may be made to Nikitin (259).

The essential nature of many micro-elements was doubted for a pretty long time on account of lack of appreciation of the inherent difficulties associated with such investigations, e.g., low requirement often satisfied by supply in seeds, traces available as contamination in sand, water and culture vessel, poor aeration of the solution, improper physiological balance amongst nutrients, inadequacy in maintaining the pH within certain limits and lack of knowledge about the interaction between climatic conditions and nutrient supply. With improvement in technique, the utility of micro-elements became obvious. Methods have been evolved for obtaining physiologically balanced nutrient solutions (8, 9, 10) and solutions free from heavy metals (178, 179). Mechanical devices for controlling the flow and aeration of nutrient solutions, and for maintaining known conditions of illumination, humidity and temperature (180-188), have been successfully designed with the result that nutrient cultures are claimed by some investigators as an alternative method for the economic production of crops (189, 190, 191).

The utility of nutrient solutions has been found to depend upon the crop, criterion of growth, parts of the plant sampled, characters used for determining optimum nutrient ratios, total osmotic concentration, individual salt proportions (260, 261, 262) and environmental conditions. Of the enviornmental conditions, temperature and light have, as marked an effect as the nature of the medium, sand or water culture, or the composition of the nutrient solution. Aeration is another important factor in all nutrient studies for intake of salts is now known to depend largely upon the oxygen supply of the medium. In estimating micro-element responses, therefore, attempts have been made to grow plants under as standard conditions of these factors as possible and to vary one or two or a set of known factors at a time so as to enable a proper estimate, of the significance of response by adequate statistical methods. Systematic investigations in these directions have led to valuable results particularly under pot and field conditions and have helped in assessing the extent of damage to different crops under conditions of deficiency or excess of these micro-nutrients. An extensive survey of such problems has been made by Johnson and Woodman (255) who have presented in a connected sequence valuable information on various aspects of the development of nutrient culture studies.

Equally important are the developments in the method of estimating micro-elements in plant and soil. Several apparatus such as absorbtiometer, polarimeter, spectrograph and photoelectric colorimeters have been described and found helpful in correctly estimating traces of micro-elements (192-225). Methods useful in this connection are described by other investigators (226-250). Practical methods of estimating different micro-nutrients have also been described by Piper (251) and Stiles (17). For details of the procedure of estimation, reference may be made to these publications.

Recently, radioactive isotopes have been applied to soil and plant problems (263). According to Noggle (252), the isotope method is based on the fact that some particular property of the isotope enables the investigator to measure the proportion of that isotope present when it is mixed with other isotopes of the same element. In stable isotopes, it is the difference in mass that is easily measured; in radio-active isotopes, characteristic radiations are emitted and these are of measurable energy level. Practical use of such isotopes is limited by their extremely short life cycle. In some cases as in fluorine, manganese, cobalt, arsenic and iodine, only one stable isotope is available with the result that it cannot be used for tracer investigations. Radio-active isotopes of these elements are, therefore, more helpful but different types of radiations emitted constitute a health hazard to those handling them. Adequate shielding, short period of exposure and cleanliness of both laboratory and personnel, minimise these hazards. When properly executed, the radio-isotope method is capable of quantitative results. Radio-active isotopes of micro-elements include among others, F^{18}, Cl^{36}, Mn^{54}, Mn^{52}, Fe^{55}, Fe^{50}, Co^{58}, Co^{60}, Zn^{65}, As^{73}, Mo^{99}, I^{131}, and Pb^{212}. The possibility of stimulating plant growth by radio-active elements is also visualised.

With newer and better methods of studying plant nutrition problems, it is hoped that the role of micro-elements in plant growth and metabolism would be better understood in years to come. In its broader aspect, the essential nature of a micro-element has so far been established in the traditional manner by (i) producing characteristic deficiency symptoms artificially under conditions of nutrient culture; (ii) by correcting these deficiencies by supply of these micro-elements to the roots; and (iii) by correcting deficiencies by supplying these elements to the aerial parts of the plants (253, 254, 263). To what extent these researches have contributed to a better understanding of the problems of micro-element nutrition of crop plants is elucidated in the subsequent chapters.

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