Soil Fertility and Fertilizers

An Introduction to Nutrient Management

seventh edition

土壤肥力与肥料

养分管理导论（第7版）（影印版）

John L. Havlin
James D. Beaton
Samuel L. Tisdale
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PEARSON Education

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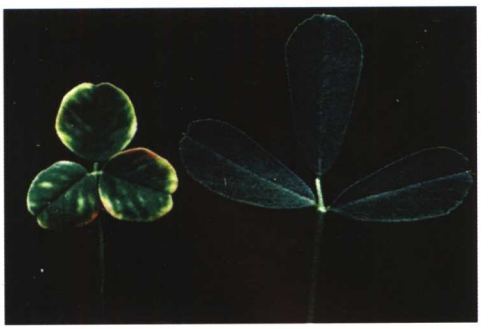
N deficiency in grain sorghum. Chlorosis occurs on older, lower leaves first as N is translocated to newer, developing leaves. Yellowing proceeds from the leaf tip down the midrib in a V-shaped pattern. Eventually necrosis or "firing" of the entire lower leaves occurs as the plant matures.

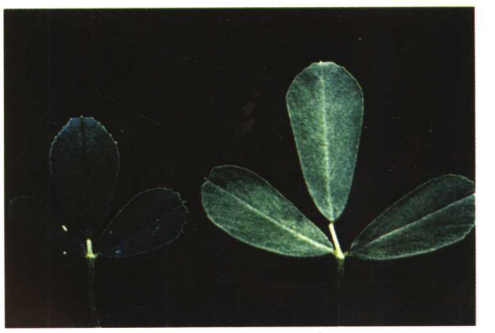
N deficiency in corn. Necrosis of lowest leaf and chlorosis of the 2nd and 3rd leaf (tip only) from the bottom is shown on the N-deficient plant on the left. Plant on the right is N sufficient.



N deficiency in alfalfa. Chlorosis occurs initially on edges of lower leaves. Necrosis of leaf edges and entire leaf occurs as plant matures. Normal plant is on the right.

P deficiency in corn. Stunted plants, delayed maturity, and progression of dark green to purple discoloration of lower leaf edges. Purple discoloration does not occur in all grasses.

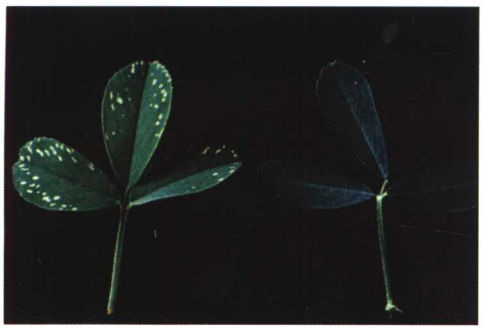
P deficiency in wheat. Plants on left exhibit poor tillering, stunted growth, delayed maturity, and yellowing of lower leaves. Normal plants are on the right.



P deficiency in alfalfa. Plant is stunted and older leaves are small and exhibit dark green to purple discoloration. Normal plant is on the right.

K deficiency in corn. Chlorosis and necrosis of edges of lower leaves, as K is translocated to newer, developing leaves. Midrib usually remains green.

K deficiency in soybean. Chlorosis and necrosis of lower leaf edges where tissue along veins and base of leaf remain green.



K deficiency in alfalfa. Small white spots occur along leaf margins, although yellowing of leave edges can also occur. Normal plant is on the right.

S deficiency in corn. Plant is stunted with light green and/or yellow leaves. Although usually occurring on newer leaves, symptoms can be observed on the entire plant. S deficiency symptoms can be confused with N deficiency.

S deficiency in wheat. Chlorotic newer leaves are observed, as S is not translocated from older to newer leaves as readily as N.

S deficiency in soybean. Plant is stunted with light green and/or yellow newer leaves.

Mg deficiency in corn. Interveinal yellowing or white discoloration beginning with lower leaves, as Mg is translocated from older to newer leaves. Can be confused with Fe deficiency.

Fe deficiency in grain sorghum. Severely stunted plant with interveinal chlorosis of entire leaf, occuring in newer leaves first. Leaves turn white under severe Fe stress.

Fe deficiency in strawberry. Interveinal chlorosis of newer leaves.

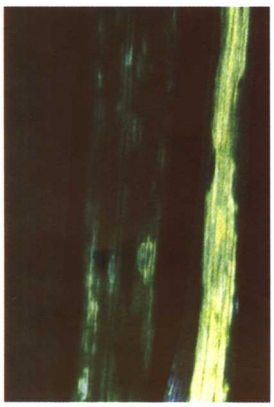
Zn deficiency in corn. Newer leaves exhibit bleached white or pale yellow discoloration in area between leaf edge and midrib.

Zn deficiency in corn. Severe stunting caused by shortening of internodes. Normal plant is on the right.

Mn deficiency in corn. Pale green to yellow discoloration between veins of newer leaves. Can be confused with Fe deficiency.

Mn deficiency in soybean. Pale green interveinal chlorosis of newer leaves.

Cu deficiency of corn. Pale yellow to white discoloration of newer leaves that progresses to necrosis of leaf tips and edges.



Cu deficiency of wheat. Chlorosis and necrosis of newer leaves. Can be mistaken for leaf diseases.

Mo deficiency of cauliflower. Newer leaves exhibit wilting and necrosis or "die-back" along edges.

B deficiency of alfalfa. Stunted plants with chlorosis of newer leaves.

Cl deficiency in wheat. Chlorosis and necrosis on leaf edges and tips of older leaves. Can be mistaken for leaf diseases.

郑重声明

序　言

“民以食为天、食以土为本”，土壤肥料学科是农业领域中的基础学科，而土壤肥料行业又是国家的基础行业。一方面作物要高产稳产，离不开土壤肥力的保育和施用肥料。最新的社会经济学研究表明，一个地区或一个国家的经济繁荣与该地区或该国家的土壤肥力成显著正相关，这充分说明培育土壤肥力和合理施肥在农业乃至整个国家可持续发展中的重要性。另一方面，生态环境要得到保护同样也离不开养分资源的合理管理。目前化学氮肥利用率低、损失严重而污染环境是一个全球性问题，在中国经济发展突飞猛进的今天尤其显得突出，这就需要我们确立现代农业应该兼顾农业生产和环境保护双重任务的理念，只有更新了观念，才能使我们的工作到位。综上所述，养分是一把双刃剑，用得好就能确保作物持续高产，用不好就会污染环境。

土壤肥料课程作为农业大学中的一门农业基础课程，授课的学生面越来越宽，涉及的专业有农学、种子生产学、植物保护学、园艺学、设施农业、草业科学、生态学、环境科学、环境工程、中药生产学等，学生掌握了土壤肥料的知识非常有利于今后从事涉农和环保领域的工作。以美国为例，目前从事环境研究与治理的人员中，有很多人是毕业于土壤肥料专业的，几乎所有人员都具有土壤肥料知识背景，这就是目前我国所有的农业大学中原“土化”专业都改成了“农业资源与环境”专业的背景所在。

近年来大学教学体系不断深化改革，由过去大学本科专业教育太深、太窄逐步过渡到本科教育厚基础、宽口径的培养模式。与之相对应的，就应该对过去的教材作大幅度的改编。此外，目前大学教学中的双语教学方兴未艾，但困扰之一就是双语教材问题。我们原准备在国内组织相关专家编写一本土壤肥料与植物营养的英文教材用于双语教学，但考虑到英语毕竟不是我们的母语，如果表达不地道，会产生误人子弟的后果。受高等教育出版社的委托，我在国外的相关书籍中筛选出了这本教材，即《土壤肥力与肥料　养分管理导论》（第7版），推荐作为农业大学中土壤肥料课程的教材，该书对当前市场经济中土壤肥力和养分管理等问题论述深入浅出，详细介绍了土壤中的化学、生物和物理基本过程以及影响土壤营养元素有效性的相互作用过程。此书内容安排紧凑、前后呼应，在论述了土壤-植物关系、酸性和碱性土（世界两大类土壤）之后，详细讨论了植物营养元素的土壤和植物行为及其肥料特征，之后又论述了养分管理的基本问题和实践措施。此书深度和广度适中，理论与实际联系紧密。最可贵的是该书每章后面的思考题具有很强的启发性和综合概括力，非常有助于学生思考和讨论，也有助于培养学生的创新思维能力。

此书除了适合于上面提到的几类专业的本科生外，对农业大学中农业资源环境专业学生的植物营养学课程也是一本很好的参考书，尤其是该专业的学生可以通过阅读这本书提高本专业领域的英文写作能力，会对今后继续深造有很大的帮助。教师在采用此书时要注意结合中国土壤肥料的具体情况，要减少美国的实例，而尽量增加中国的实例。比如在讲述肥料章节中要注意碳酸氢铵和过磷酸钙的详述，因为这些肥料目前在中国施用面还是很广。又如在讲述作物营养章节中要注意增加水稻作物营养与施肥的内容，因为中国是一个生产水稻的大国。如此修正，定会收到很好的效果，以真正达到洋为

中用的目的。

本人从1980年开始从事土壤肥料的研究工作，至今已有26个年头了，数十年的研究经历使我对土壤肥料行业产生了浓厚的兴趣，虽然没有杰出的成就，但自我感觉我们所从事的工作对国家、对人民都很重要，于是乎，一直给我的学生唠叨，希望能培养出他们的兴趣，激发出他们的热情，虽然效果不是很大，但也不乏有学生已在土壤肥料行业中取得了卓著的成绩。在此书引进出版之时，出版社让我写个序言，我最大的心愿就是希望学生读完这本书后，对土壤肥料行业产生兴趣，从此，我们可以交流不息，友情永存。

沈其荣

2006 年 7 月于南京

Preface

Soil Fertility and Fertilizers: An Introduction to Nutrient Management, seventh edition, was first published in 1956 under the title *Soil Fertility and Fertilizers.* Although this seventh edition has been substantially revised to reflect rapidly advancing knowledge and technologies in plant nutrition and nutrient management, the outstanding contributions of Dr. Samuel L. Tisdale (1918–1989) and Dr. Werner L. Nelson (1914–1992) will always be remembered and appreciated.

The importance of soil fertility and plant nutrition to the health and survival of all life cannot be overstated. As human populations continue to increase, human disturbance of the Earth's ecosystem to produce food and fiber will place greater demand on soils to supply essential nutrients. Therefore, it is essential that we increase our understanding of the chemical, biological, and physical properties and relationships in the soil-plant-atmosphere continuum that control nutrient availability.

The soil's native ability to supply sufficient nutrients has decreased with higher plant productivity levels associated with increased human demand for food. One of the greatest challenges of our generation will be to develop and implement soil-, crop-, and nutrient-management technologies that enhance plant productivity and the quality of the soil, water, and air. If we do not improve and/or sustain the productive capacity of our fragile soils, we cannot continue to support the food and fiber demand of our growing population.

To the Student

The goal of this book is to impart to the student a thorough understanding of plant nutrition, soil fertility, and nutrient management so that she or he can (1) describe the influence of soil biological, physical, and chemical properties and interactions on nutrient availability to crops; (2) identify plant nutrition–soil fertility problems and recommend proper corrective action; and (3) identify soil- and nutrient-management practices that maximize productivity and profitability while maintaining or enhancing the productive capacity of the soil and quality of the environment.

The specific objectives are to (1) describe how plants take up or absorb plant nutrients and how the soil system supplies these nutrients; (2) identify and describe plant-nutrient deficiency symptoms and methods used to quantify nutrient problems; (3) describe how soil organic matter, cation exchange capacity, soil pH, parent material, climate, and human activities affect nutrient availability; (4) evaluate nutrient and soil amendment materials on the basis of content, use, and effects on the soil and the crop; (5) quantify, using basic chemical principles, application rates of nutrients and amendments needed to correct plant nutrition problems in the field; (6) describe nutrient response patterns, nutrient-use efficiency, and the economics involved in nutrient use; and (7) describe and evaluate soil and nutrient management practices that either impair or sustain soil productivity and environmental quality.

To the Teacher

Motivate your students to learn by showing them how the knowledge and skills gained through the study of soil fertility will be essential for success in their careers. Use teaching methodologies that enhance their critical thinking and problem-solving skills. In addition to understanding the qualitative soil fertility and plant-nutrition relationships, students must know how to quantitatively evaluate nutrient availability and nutrient management. Environmental protection demands that nutrients be added in quantities and by methods that maximize crop productivity and recovery of the added nutrients.

Since some of the examples used in this text may not be representative of your specific region, frequently integrate additional field examples from your region to illustrate the qualitative and quantitative principles. Strongly reinforce the reality that production agriculture, sustainability, and environmental quality are compatible provided soil-, crop-, and nutrient-management technologies are used properly. Develop in your students the desire and discipline to expand beyond this text through reading and self-learning. Demand of your students what will be demanded of them after they graduate—to think, communicate, cooperate, and solve problems from an interdisciplinary perspective.

An instructor's manual is available from the publisher and provides qualitative and quantitative information pertinent to each chapter. Instructors should utilize the questions at the end of each chapter as learning aids to help students gain confidence with the material and to prepare for exams. Answers to each question and complete solutions to quantitative calculations are provided in the instructor's manual.

We hope your students find the text a valuable resource throughout their careers. Please feel free to provide suggestions for enhancing the effectiveness of the text as a teaching and learning aid.

John L. Havlin
James D. Beaton

目　录

Contents