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Please note: In the Table of Contents, kinds of seeds are grouped according to older family names. Newer family names are listed in [brackets] in the appropriate section as well as in the Index.

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The "Handbook for Seedling Evaluation", 1979, published by the International Seed Testing Association (ISTA) inspired the initiation of this work. Early discussions with Drs. Jan Bekendam and Regula Schmitt of the ISTA Germination Committee were particularly helpful.

The following members of the AOSA Seedling Evaluation Committee actively participated in the planning and preparation of various stages of this handbook: Doug Ashton (Chairman), Barbara Atkins, Ellen Chirco, Prof. Leroy Everson, Dr. Wayne Guerke, Beverley Jackson, Bob Karrfalt, Susan Maxon, Paul Peterson, Jeff Ruprecht, John Scott, Terry Turner and Coralie Wilson. Earlier members of the Committee included A. B. (Sandy) Ednie, Oscar Hall and Harry Smith.

The drawings of the first edition were prepared by Susan Laurie-Bourque. Doug Ashton selected the seedlings for the drawings and edited the Handbook. Descriptions for the Apiaceae, Caryophyllaceae, Geraniaceae, Primulaceae, Scrophulariaceae, Solanaceae and Violaceae were prepared by Aleta Meyr and Susan Alvarez, Ransom Seed Laboratory. Deborah Meyer, California Department of Food and Agriculture, prepared the drawings for the Balsaminaceae, Caryophyllaceae, Geraniaceae, Solanaceae I and Violaceae. The drawings of corn-Figure 7 were prepared by Patrick Dechavanne of the Station Nationale d'Essais de Semences, France. Sarah Damen of SGS Brookings, South Dakota, prepared the Tropaeolaceae section. Many other persons made substantial contributions to the preparation and review of the descriptions; their suggestions and encouragement were invaluable.

In 2002 the format of the Seedling Evaluation Handbook was modified to accommodate conversion from a printed publication to a digital format available on compact disk (CD). The new format will better facilitate future updates and additions to the handbook. While no substantive changes were made to the handbook, section numbers for the seedling evaluation groups were eliminated and figure numbers were modified accordingly to allow for easy insertion of new seedling description groups as they become available. References to the AOSA Rules for Testing Seeds were updated to reflect changes that have been adopted by the Association of Official Seed Analysts since the handbook was first published. In addition, the illustrations were individually scanned and digitally enhanced for clarity. This work was completed at the California Department of Food and Agriculture, Seed Laboratory.

PREFACE

This Handbook is a part of the AOSA Rules for Testing Seeds, effective October 1, 1992, as set forth in section 6.5 b (2) of the Rules. It replaces the seedling descriptions formerly contained in Appendix 1 of the Rules.

The text and drawings of the Handbook were first published as Rules change proposals in AOSA Newsletters 63(2) and 65(1). The proposals, with amendments, were adopted by the Association at the 1989 and 1991 annual meetings. Throughout the development of the Handbook, there was consultation with and review by member laboratories of both the Association of Official Seed Analysts and the Society of Commercial Seed Technologists.

The Handbook is the culmination of several years' work by the Seedling Evaluation Committee. The Committee's objectives were to remove ambiguity from the descriptions, standardize the terminology used across the descriptions, introduce supplemental information and illustrate the descriptions through the use of line drawings. The ultimate goal, of course, was to increase between-laboratory and between-analyst uniformity in seedling evaluation.

The Committee recognizes that there is still much room for improvement; for example there should be descriptions for the families now lumped in the "Miscellaneous" section, more drawings are needed to more fully cover the range of seedling abnormalities that may be observed, and some of the descriptions could be expanded. Users of the Handbook are encouraged to conduct research in support of new descriptions or to validate existing ones, and to submit these to the Rules Committee for consideration by the Association.

In 2009, Handbook 35 was renamed AOSA Rules for Testing Seeds Volume 4. Seedling Evaluation, to clarify the status as a document of official seed testing procedures.

Please note: In the 2016 version of Volume 4, changes were made to the seedling evaluation of Asteraceae I (lettuce). Section 3.4.9 was modified to expand the list of sensitive species used in testing germination substrata for toxicity. Section 3.5.10, a description of decay at the point of attachment of the cotyledon and terminal bud decay, was added. The publication date has changed on all pages to reflect the current CD version. Maintaining a current set of the AOSA Rules for Testing Seeds is the analyst's responsibility

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PART I. PRINCIPLES OF SEEDLING EVALUATION

1 INTRODUCTION

Laboratory test results are used as a basis for buying and selling seed, for the labeling of seed as required by federal and state laws, and for monitoring the labeling to ensure it is current and truthful. Since it is essential that accurate test information be provided, all commercial and official seed testing laboratories must follow accepted rules for testing. These rules must be fully explained and standardized.

A major step towards standardization was taken in 1952 with the publication of USDA Handbook 30, "Testing Agricultural and Vegetable Seeds". This book provided valuable information on seed testing, including the first descriptions of normal and abnormal seedlings. In 1960, the Handbook 30 descriptions were modified to form prescriptive statements and appended to the AOSA Rules for Testing Seed. As Appendix 1 to the Rules, the descriptions received "official" status.

While the addition of the seedling descriptions to the Rules was an important step towards uniformity in germination testing, most of the supplementary information included in Handbook 30 was not included. In addition, it had been recognized for some time that some ambiguities and gaps existed in the descriptions. In 1978, therefore, the Association undertook a review of Appendix 1 with the aim of updating and clarifying the descriptions. Many analysts also expressed the wish to have supplemental information and illustrations included that would provide a basis for the understanding of the descriptions.

The objective of this volume is to further standardize the evaluation of seedlings by providing, in addition to the evaluation rules, a training aid and working reference that includes: botanical information on seeds and seedlings; a glossary of relevant terms; seedling evaluation criteria replacing Appendix 1 of the Rules; information on factors affecting the appearance of seedlings; and drawings of normal and abnormal seedlings.

2 CLASSIFICATION, STRUCTURE AND DEVELOPMENT

Botanical sciences basic to the understanding of seeds and seedlings are: taxonomy, the study of the classification of plants; morphology, the study of the internal and external structure of plants; and physiology, the study of the life processes of plants. Information from these fields of botany provides the seed analyst with knowledge important to the understanding of their work.

2.1 The Classification of Plants

2.1.1 Scientific names. In referring to a plant, either its common name or its scientific name may be used. The plant's scientific name consists of a binomial composed of the genus name (e.g. *Medicago*) and the species name (e.g. *sativa*). Further subdivisions such as subspecies or variety may exist. The scientific name provides information on the family relationship of the plant, which often is useful. For example, you would know that *Medicago sativa* and *Medicago lupulina* are closely related, a fact that you probably would not deduce from the common names alfalfa and black medick. In addition, scientific names are essentially standardized throughout the world, while common names vary from region to region, often resulting in confusion. For example, *Medicago sativa* is known as alfalfa in the United States and Canada but as lucerne in many other countries. The seed analyst is advised to learn the scientific names of the species that are encountered in the laboratory.

Family names usually end in "-aceae"; however, there are eight families, named before standardization of botanical nomenclature, for which two names exist. While the older, traditional names are still valid, the AOSA has elected to adopt the form with the standardized "-aceae" endings. The eight families and their synonyms are as follows:

Apiaceae = Umbelliferae
Arecaceae = Palmae
Asteraceae = Compositae
Brassicaceae = Cruciferae
Clusiaceae = Guttiferae
Fabaceae = Leguminosae
Lamiaceae = Labiatae
Poaceae = Gramineae

2.1.2 Taxonomy. Taxonomy is the science of classification dealing with the arrangement of plants and animals into categories according to their natural relationships. One of these categories, the seed bearing plants, is divided into the gymnosperms (that include, for example, the conifers), and the angiosperms, or flowering plants.

The angiosperms are divided into two sub-classes: dicotyledons (possessing two cotyledons), and monocotyledons (possessing one cotyledon). The major agricultural and vegetable crops are members of two families of the monocotyledons and about 15 families of the dicotyledons.

The two most important monocotyledonous crop families are the Poaceae, with corn, cereal crops and lawn and pasture grasses being examples, and the Liliaceae, which includes asparagus and onion. The remainder of our agricultural and vegetable crops are dicotyledonous. Three examples are: Fabaceae, including beans, clovers and peas; Asteraceae, with the main crops being sunflower and lettuce; and Cucurbitaceae, which includes cucumbers, pumpkins and squash.

2.2 Seed Development

2.2.1 The ovule. A seed is a mature fertilized ovule containing an embryonic plant; usually it has nutrient storage tissue and is surrounded by a protective coat, the testa. Differentiation of a cell in the wall of the ovary initiates the development of an ovule. Each ovule begins as a dome shaped swelling referred to as the nucellus. One or two ring-like layers of tissue form around the base of the nucellus. These layers, the integuments, grow until they surround the entire nucellus, except for a tiny pore where they come together. The pore is known as the micropyle, while the collective term used for the integuments is "testa" (seed coat). The stalk connecting the ovule to the ovary wall is called the funiculus, with its place of attachment to the integuments being termed the hilum. Inside the ovule, the embryo sac develops from a specialized cell of the nucellus called the megaspore.

2.2.2 Fertilization. For every angiosperm ovule that later becomes fertilized, a pollen grain must germinate on the stigma of the pistil and grow down the style to the embryo sac. As the pollen tube enters the embryo sac it disintegrates and the contents are discharged. Each of two specialized cells from the pollen tube fuses with cells of the embryo sac. One of these fusions results in the development of the embryo, while the other results in the development of the endosperm tissue. These two fusions are referred to as "double fertilization".

With gymnosperms the pollen is drawn inside the integuments by the pollen drop. The pollen tube grows through the female gametophyte to the egg cell. Only the egg cell is fertilized, giving rise to an embryo.

2.2.3 Storage tissue. The storage tissue in seeds may originate from four sources depending on the species:

a. **Perisperm.** The nucellus may persist as the storage tissue, in which case it is referred to as "perisperm". In *Beta vulgaris* (beet) the storage tissue is perisperm and there is little or no development of the endosperm following fertilization.

b. **Endosperm.** Endosperm is one of the products of double fertilization, and in some species, particularly those of the Poaceae, it develops as the storage tissue. In this event, little or no nucellus tissue remains, and the extent of cotyledon development varies.

c. **Cotyledons.** In some species the embryo continues to grow until the endosperm is absorbed and replaced by the enlarging cotyledons (e.g. *Phaseolus vulgaris*). For other species or genera, the perisperm and/or endosperm may persist in varying degrees together with the cotyledons.

d. **Female gametophyte.** In gymnosperms the nutritive tissue is the mature female gametophyte, sometimes also referred to as the primary endosperm because it is already present before fertilization.

2.2.4 The embryo. The product of one of the fusions of the angiosperm fertilization process is the embryo (the other being the endosperm). In gymnosperms the embryo is the only product of the fertilization process. Depending on the species, the embryo develops to varying degrees within the seed, becoming a "miniature plant" by the end of the growing season. In *Phaseolus vulgaris*, for example, the embryo is fully developed and the radicle, hypocotyl and epicotyl with primary leaves can easily be observed. The development of the embryo in other species may be much less, with some essential structures being observed only after considerable growth of the seedling.

2.3 Definition of the Seed

Botanically, a seed is a mature fertilized ovule containing an embryonic plant; usually it has nutrient storage tissue and is surrounded by a protective coat, the testa. This structure is a "true seed"; however, the ovules of many species have additional structures of the mother plant attached or fused to the seed coat. For example, the "seed" of *Triticum aestivum* (wheat) is botanically a fruit because the pericarp (ovary wall) is fused with the seed coat. In this handbook the term "seed" will be used in the agronomic sense (i.e. the true seed plus any accessory structures that may be attached when it is planted in the field; see section 3.2 of the AOSA Rules for Testing Seeds Vol. 1).

2.4 Seedling Structure

2.4.1 Dicotyledons and gymnosperms.

a. The root. The root system serves three major functions: (1) to anchor the plant in the soil, (2) to absorb water and dissolved salts from the soil and (3) to conduct the water and salts to the hypocotyl, cotyledons and epicotyl. The embryonic root, or radicle, is located at the basal end of the embryo and is usually the first seedling structure to rupture the testa. After emergence it is referred to as the primary root. The primary root elongates rapidly and soon numerous root hairs develop, greatly increasing the absorbing surface of the roots. As the seedling continues to grow, secondary roots develop from the primary root and from other secondary roots. Roots may also emerge from other structures (e.g. the hypocotyl) and are referred to as adventitious roots.

b. The hypocotyl. The portion of the seedling axis between the root and the cotyledons is the hypocotyl. The hypocotyl is a transition structure for the transport of water and dissolved salts from the roots to the epicotyl. When a seed with epigeal germination (see section 2.5 for definitions of epigeal and hypogeal germination) is planted in moist soil, the hypocotyl elongates carrying the cotyledons above the soil surface.

c. The Cotyledons. The cotyledons are the storage structures of the embryo. They may be only a small portion of the seed in species with endosperm, perisperm or female gametophyte storage tissue, or they may occupy a large portion of the embryo when they are the primary storage tissue (e.g. *Phaseolus vulgaris*). In epigeal species, the cotyledons may grow quite large and become the first photosynthetic structures of the young plant. In hypogeal species the primary function of the cotyledons is to provide nutrients to the growing seedling until it can produce its own nutrients. In most species the cotyledons shrivel and drop off as their reserves are depleted. In a few species (e.g. *Cucurbita pepo*, pumpkin) the cotyledons may persist well beyond the seedling stage of growth.

d. The Epicotyl. The epicotyl includes all seedling structures above the cotyledons. In species with epigeal germination (e.g. *Phaseolus vulgaris*), the epicotyl, cotyledons and part of the hypocotyl emerge from the soil. In species with hypogeal germination (e.g. *Pisum sativum*), only the epicotyl emerges, carrying the first foliage leaves above the soil surface. In these species, the epicotyl also bears one or more scale leaves. Dormant meristematic buds in the axils of these scale leaves become active if there is damage to the terminal bud. The conducting tissue of the epicotyl transfers water and nutrients from the hypocotyl and cotyledons to the leaves and terminal bud above.

e. The Terminal Bud. The terminal bud occupies the tip of the epicotyl and consists of the apical meristem surrounded and protected by the developing leaves.

2.4.2 Monocotyledons.

a. The Root. As in the dicotyledons, the monocotyledon root system serves to anchor the plant in soil, absorb water and dissolved salts from the soil and to conduct the water and salts to the growing seedling.

The embryonic root, or radicle, is situated at the basal end of the embryo and, in the case of the Poaceae, its apex is covered by the coleorhiza. After the radicle emerges it is referred to as the primary root. In some species of the Poaceae (e.g. *Triticum*) the primary root is indistinguishable from the other roots that develop from the scutellar node region and hence all of these are referred to as seminal roots. Roots that develop from structures above the scutellar or cotyledonary node are called adventitious roots. Secondary roots may develop from seminal and adventitious roots.

b. The Hypocotyl and Mesocotyl. In monocotyledons the hypocotyl is usually not discernible as a separate structure. The mesocotyl is the part of the seedling axis between the scutellum and the base of the coleoptile. In some species (e.g. *Zea mays*) the elongation of the mesocotyl may be considerable. In others (e.g. *Triticum aestivum*) the elongation may be imperceptible. Elongation of the mesocotyl is suppressed by light after the coleoptile emerges from the soil.

c. The Cotyledon. In the monocotyledons the cotyledon absorbs nutrients from the endosperm and transfers them to the growing seedling. In the Poaceae the cotyledon is called the scutellum. It is in close proximity to the endosperm and is laterally attached to the embryo axis. In *Allium* (Liliaceae) the cotyledon tip remains embedded in the endosperm to absorb nutrients but the cotyledon also emerges from the soil (i.e. germination is epigeal) and becomes photosynthetic.

d. The coleoptile. The coleoptile is only present in species of the Poaceae. It is a leaf-like, cylindrical sheath enclosing the terminal bud of the embryo and the developing leaves of the young seedling. The coleoptile provides protection for the leaves as they push up through the soil. After emergence from the soil, growth of the leaves ordinarily causes the coleoptile to split downward from the tip. The coleoptile does not persist beyond the seedling stage.

2.5 Seedling Growth Habit

2.5.1 Epigeal germination. Epigeal means "above the earth", referring to the cotyledons that are raised above the soil surface after the seed germinates. In the dicotyledons and gymnosperms the hypocotyl forms an arch and, as it elongates, the cotyledons with the terminal bud enclosed are pulled above the soil surface. The hypocotyl straightens as it continues to elongate. In the monocot *Allium cepa*, the cotyledon itself elongates and emerges from the soil. In this case there is little or no significant hypocotyl elongation.

2.5.2 Hypogeal germination. Hypogeal means "below the earth", in reference to the position of the cotyledons. In hypogeal species there is little or no hypocotyl elongation; the cotyledons remain below the soil surface and the primary leaves become the first photosynthetic structures, rather than the cotyledons. In some species (e.g. *Pisum sativum*) the epicotyl elongates and pushes the terminal bud above the soil surface. In many species of the Poaceae (e.g. *Zea mays*) the mesocotyl elongates bringing the terminal bud to, or just below, the surface.

2.6 The Germination Process

When moisture is supplied to dry seeds water enters by imbibition, resulting in swelling of the embryo tissues. During imbibition the seed coat softens and becomes more permeable to water and gas. Cellular tissue is hydrated and the germination process begins if conditions of temperature, gas concentration and light are favorable. Enzymes are activated, starch is converted into sugar, fats into soluble compounds and proteins into amino acids. Nutrients are transferred from the storage tissues (endosperm, perisperm, female gametophyte tissue or cotyledons) to the root-shoot axis of the embryo. Growth may begin by cell elongation or by cell division and the radicle emerges from the seed. The hypocotyl or epicotyl elongates and the seedling emerges from the soil.

3 SEEDLING EVALUATION

To determine the percentage germination of a sample it is necessary to evaluate the essential structures of the seedling. In order to establish uniformity between laboratories in this assessment, seedling descriptions have been developed and form Part II of this Handbook. There are many factors that interact to affect the appearance of seedlings in the laboratory. The analyst must have an understanding of these factors to evaluate the potential of the seedling to continue development.

3.1 Laboratory Definition of Germination

In seed laboratory practice, germination is the emergence and development of the essential structures of the seed embryo that, for the kind of seed in question, are indicative of the ability to produce a normal plant under favorable conditions. The objective of the germination test is to determine the percentage of normal seedlings in the test. (See section 6.2 a of the AOSA Rules for Testing Seeds Vol. 1.)

3.2 Germination vs. Vigor

Germination test results correlate well with emergence under favorable field conditions. The germination test is not intended to consider the vigor of the seed. Since the vigor of a seed lot refers to its ability to produce seedlings under diverse conditions (e.g. cold or hot weather, wet or dry soil, varying storage periods, etc.) it is evident that a vigor test must be planned to determine the performance of a seed lot under specific environmental conditions. The laboratory germination test is not designed to provide vigor information. Rather, its purpose is to establish the maximum plant-producing potential of a seed lot. Vigor testing methods are described in the Vigor Testing Handbook: Contribution No. 32 to the Handbook on Seed Testing, AOSA, revised 2002, and subsequent updates.

3.3 Assessment of Seedlings

3.3.1 Normal seedlings. In general, seedlings are classified as normal if they have no defects or only slight defects that will not impair the continued development of the seedling or plant when grown in soil under favorable conditions. (See section 6.2 b of the AOSA Rules for Testing Seeds Vol. 1.)

3.3.2 Abnormal seedlings. Seedlings are classified as abnormal if they have defects that will prevent them from developing into mature plants when grown in soil under favorable conditions. These defects are not to be considered abnormalities if they are caused by test conditions. To classify a seedling as abnormal the analyst must judge the defect to be so severe that further development of the seedling would be unlikely. Specific abnormalities are listed in the seedling descriptions of Part II. (See section 6.2 c of the AOSA Rules for Testing Seeds Vol. 1.)

3.4 Causes of Seedling Abnormalities

There are many causes of seedling abnormalities. If seedlings are difficult to assess or the analyst suspects that the defects may be exaggerated on the "artificial" germination substrata (particularly if chemical injury or the presence of disease are involved), it is advisable to retest the seed in sand, soil or a sand/soil mixture. (See sections 6.5 b (1) and 6.6 d of the AOSA Rules for Testing Seeds Vol. 1.)

3.4.1 Mineral deficiencies in the soil. Crops grown on soils with mineral deficiencies may produce seeds that produce abnormal seedlings when germinated. The abnormals are usually characterized by shrunken, hollow, brown or pithy areas on the cotyledons. They may also have decayed areas on the cotyledons, hypocotyls, epicotyls or roots and may be stunted and undeveloped.

A calcium nitrate solution may be used for overcoming hypocotyl collar rot of bean seedlings, but chemical treatments have not yet been authorized for other types of mineral deficiencies. (See sections 6.8 j and 6.9 j of the AOSA Rules for Testing Seeds Vol. 1). The analyst should learn to recognize mineral deficiencies as discussed under the various family groups.

3.4.2 Frost damage. Freezing temperatures when seeds on the plants are in the developmental stage can cause damage to the seed. The degree of damage depends on the species, the stage of seed development and severity of the frost. Germination and growth may be initiated in frost-damaged seeds but the resultant seedlings are often too weak to produce normal plants. Seedlings from frost-damaged seeds of the Poaceae may be characterized by grainy coleoptiles and spirally twisted leaves as well as decay at the point of attachment to the scutellum.

3.4.3 Heating. Over-heating can occur if seed is too moist when the crop is harvested and it is not given an opportunity to dry before further storage. Fungal activity plays a major part in temperature increase in moist seed. Heated seed often shows a high percentage of dead and moldy seeds, or seedlings that decay after sprouting. Seedlings may have missing roots or epicotyls or, in the Poaceae, missing, stunted or empty coleoptiles. Heating may also result in decay at the point of attachment to the scutellum. Damage may range from minor to severe and seedlings may be difficult to evaluate.

3.4.4 Mechanical damage. Mechanical breakage of seeds may occur during harvesting, threshing, loading, hauling, unloading, and cleaning operations. Mechanical damage to grass seed and especially to some of the range grasses may occur during combining or in special milling processes designed to remove weeds or accessory seed structures. Large-seeded legumes such as field and garden beans, lima beans, soybeans and peas are especially susceptible to threshing or combine damage. Seed that has been mechanically damaged may produce seedlings with damaged primary roots, hypocotyls or epicotyls, or broken or detached cotyledons. Bruised areas are usually necrotic or decayed. Other legume seeds such as the larger seeded clovers and vetches may be damaged to a lesser extent in threshing. Some damage may occur during scarification intended to reduce the hard seed content in legume seeds. Damage at the point of attachment of the cotyledons may be difficult to evaluate if seedlings are removed too early in the test period.

3.4.5 Insect damage. Seeds that have become infested with insects may produce seedlings that lack essential seedling structures or are weak and stunted. In some cases the adult insect lays her egg in the developing ovule and the damage is caused by the larvae eating away the tissues inside the seed coat. Examples of these include weevil damage to seed of field peas, cowpeas and vetch, and chalcid fly damage to alfalfa and red clover seed. Some storage insects eat away the embryo and scutellum and leave the endosperm, in which case the seed will not germinate. Other insects eat the endosperm and leave the embryo, which may germinate but be too weak to continue development.

3.4.6 Chemical treatment injury. Some fungicides or insecticides, used for seed treatment, can cause abnormal seedlings in germination if excess amounts of the chemicals are used. When seeds have been "over-treated" and planted on "artificial" substrata the seedling roots and hypocotyls may become stunted and swollen. In severe cases, some essential seedling structures may be destroyed.

When insecticides or herbicides are used in the field they may affect the seed produced, particularly if treatment occurs at the early stage of seed development. A more common cause of insecticide or herbicide damage is storage of seed near these chemicals in a warehouse. Seed mailed in "empty" herbicide bags or boxes have been observed to produce abnormal seedlings in the germination test.

Retesting in sand or soil is recommended when damage due to chemical exposure is suspected. (See section 6.6 d of the AOSA Rules for Testing Seeds Vol. 1.)

3.4.7 Declining vigor. Seeds that are old, or have been subjected to unfavorable storage conditions are usually slow to germinate. (See sections 6.9 d (4) and (5) of the AOSA Rules for Testing Seeds Vol. 1.) Seedlings may be weak and watery in appearance. Some of the essential structures may be stunted or lacking and saprophytic fungi may interfere with growth. (See section 6.5 a of the AOSA Rules for Testing Seeds Vol. 1.)

3.4.8 Pathogenic infections. Although seed infected with pathogenic organisms may initiate growth, one or more of the essential seedling structures may be damaged or destroyed by fungi or bacteria. Since the manifestation of disease on the seedlings is dependent on the environmental conditions during germination, test results may be erratic. When the seedlings of a test are badly infected with pathogenic organisms, the germination analyst must be careful in differentiating between primary and secondary infections. Retests in sand or soil are recommended when evaluation of seedlings is difficult. See also section 3.5.5, diseased and decayed seedlings. (See sections 6.5 a and 6.6 of the AOSA Rules for Testing Seeds Vol. 1.)

3.4.9 Toxicity in the laboratory. If seed is planted on substrata placed directly on galvanized trays, or galvanized trays coated with a thin copper finish, the seedlings may show zinc toxicity. The most common symptom of zinc toxicity is stunted, thickened and discolored roots. If galvanized trays must be used, they should be covered with plastic or waxed paper or the seeds should be planted in a container that can be placed on the tray.

Artificial substrata such as towelling, blotters and creped cellulose may contain chemicals toxic to seedlings. Laboratories should purchase only artificial substrata produced for seed testing. Paper towels intended for the washroom and creped cellulose produced for packaging are not suitable. Sulfuric acid not thoroughly rinsed from the paper pulp, sizing sometimes used to give paper a hard surface or binders intended to hold paper together may be sources of the toxicity.

Tap water containing toxic chemicals may cause germination failure, root inhibition or other seedling abnormalities. Distilled water should not be beyond suspicion; it could have a low pH that may adversely affect germinating seeds.

Germination substrata or water from new or unknown sources should be tested for phytotoxicity prior to routine use. Plant seeds of sensitive species (e.g. celery, celeriac, chicory, dandelion, timothy, lettuce, sorghum, red top, weeping lovegrass, red fescue, barley, garden cress, petunia, onion, or bermudagrass) on the substrate to be tested as well as on a similar substrate known to be non-phytotoxic. At least two species should be included in the test. Stunted roots or hypocotyls, or roots that arch away from the substrate are signs of phytotoxicity. A comparison of the test and control samples should be made daily, because the symptoms may be more difficult to see once the roots become entangled. (See third paragraph of section 6.9 a of the AOSA Rules for Testing Seeds Vol. 1.)

3.5 Factors Affecting Seedling Evaluation

3.5.1 Timing of the seedling evaluation.

a. Preliminary or first count. One or more preliminary counts may be required before the end of the prescribed germination period for some species. Interim counts are desirable so entanglement of the seedlings does not cause an evaluation problem at the time of the final count. The number of days given in the germination tables for the first count is only approximate, with a deviation of one to three days being permitted. (See section 6.9 d (2) of the AOSA Rules for Testing Seeds Vol. 1.) Only seedlings that are sufficiently developed to be assessed as normal should be removed at the first or interim counts. Seedlings with incomplete development should be left for the full prescribed period. Badly decayed seedlings and moldy seeds should be counted and removed at the first or interim counts to avoid the spread of infection to other seeds and seedlings. (See section 6.5 a of the AOSA Rules for Testing Seeds Vol. 1.)

b. Final Count. The germination percentage is based on the evaluation of essential seedling structures at the preliminary and final counts. For epigeal species it is recommended that the cotyledons be free of the seed coat at the time of the count. However, the degree of development of seedling structures at the final count varies by species and seed lot. In some species (e.g. *Phaseolus vulgaris*) the essential structures are well formed in the embryonic stage and are usually well developed and clearly visible at the time of the final count. In these species, if the seed coat has not been shed, it should be removed and the cotyledons and terminal bud examined to determine if they are healthy. In other species (e.g. *Daucus carota*, *Trifolium pratense*) the essential structures develop slowly and may not be fully developed at the time of the final count. In these species, the seedling descriptions indicate that presence of the structure may be assumed if the surrounding tissues are intact. Tightly adhering seed coats may be an indication that the cotyledons are necrotic or decayed; such coats should be removed and the cotyledons examined.

If at the end of the prescribed test period, the seedlings are not sufficiently developed for positive evaluation, the test may be extended two more days. (See section 6.9 d (4) of the AOSA Rules for Testing Seeds Vol. 1.) Tests may be extended five additional days for species of Convolvulaceae, Geraniaceae, Malvaceae and Fabaceae, if at the end of the regular germination period swollen seeds are present or there are seeds that have just started to germinate. (See sections 6.9 d (6) and 6.9 m (6) of the AOSA rules for Testing Seeds Vol. 1.)

3.5.2 Seedling response to moisture, light and temperature

a. Moisture. An adequate supply of water and oxygen is essential for seed germination and seedling development. Water enters seeds by imbibition, resulting in hydration of the embryo tissues and, if conditions are suitable, activation of the hormonal and enzymatic systems that initiate the germination process.

As stated in the AOSA Rules, the substratum must be moist enough to supply the needed moisture to the seeds at all times. However, the following caution is included: "Avoid supplying excessive moisture that will restrict aeration of the seeds. Except as provided for those kinds of seeds requiring high moisture levels in the germination media, the substrata should never be so wet that a film of water is formed around the seeds." Paper substrata should not be so wet that, by pressing, a film of water is formed around the finger, although for the larger seeds slightly more moisture may be required. For further information on the moisture requirements refer to section 6.3 of the AOSA Rules for Testing Seeds Vol. 1. For special moisture requirements for seeds of certain species (e.g. *Beta* spp., *Oryza sativa*, etc.) and for coated seeds, see section 6.8 and the "Specific requirements and notes" column of Table 6A of the AOSA Rules for Testing Seeds Vol. 1.

When the methods prescribe "moisture on dry side", the moistened substratum should be pressed against a dry absorbent surface such as a dry paper towel or blotter to remove excess moisture. (See section 6.9 b of the AOSA Rules for Testing Seeds Vol. 1.)

For information on preparation of sand and soil for use as germination substrates, see section 6.3 of the AOSA Rules for Testing Seeds Vol. 1.

When closed plastic containers are used for germination tests, it is seldom necessary to add water subsequent to planting, particularly if the test is of short duration. However, the germination analyst should check substrate moisture at regular intervals, regardless of test duration, to make certain that the moisture content is optimum.

b. Temperature. The effect of temperature on germinating seeds is often expressed as cardinal temperatures (i.e. the minimum, optimum and maximum temperatures) at which seeds of a species will germinate. The optimum temperature -- that temperature at which the greatest percentage of germination occurs within the shortest time -- is the temperature prescribed in the AOSA Rules for Testing Seeds Vol. 1.

The response of seed to germination temperature depends on the species, variety, region of production and the length of time from harvest to the date the test is conducted. In general, seeds produced in temperate regions require lower germinating temperatures than seeds from a tropical region. Seeds of wild species generally have lower temperature requirements than those from plants long domesticated.

Seeds of many species require a daily alternating temperature for optimum germination. The seeds of species grown in temperate or northern climates are more likely to respond to alternating temperatures than those grown in warmer climates. Ordinarily when alternating temperatures are specified in the Rules, the seed is kept at the low temperature for 16 hours and at the high temperature for eight hours. The seeds of some grass species will germinate well with a very wide alternation of temperature (e.g. 10-30°C). (See section 6.9 c of the AOSA Rules for Testing Seeds Vol. 1.)

Some kinds of seed need to be prechilled to break dormancy, particularly if testing is to be done soon after harvest. Generally, these seeds lose their dormancy with time, but in some species the dormancy may be very long-lived (e.g. some of the native range grasses, trees and shrubs). To prechill a sample, the seed is planted in or on the moist substrate and placed at a low temperature (usually 5 or 10°C) for a few days. The temperature and duration of the prechill are prescribed by the Rules. At the end of the prechilling period, the sample is transferred to the normal testing temperature. (See sections 6.9 d (1) and 6.9 n of the AOSA Rules for Testing Seeds Vol. 1.)

Temperature is an important factor in seed testing standardization. If a number of laboratories germinate the same seed sample or lot, and expect to obtain comparable test results, it is important that they use a temperature specified in the AOSA planting prescriptions (Table 6A). Daily checks should be made to ensure that the temperature prescribed in the AOSA Rules for Testing Seeds is maintained and is as uniform as possible throughout the germinator. Care should be taken to avoid temperature "over-run" for tests under, or near, the light source. "Hot spots" should be identified and eliminated wherever possible.

c. Light. The seeds of some plant species are light sensitive (with germination being either stimulated or inhibited), while others are not. Light sensitivity during seed germination depends on the species and variety as well as environmental factors that have affected the seed before and during germination. Seeds of many of the species of grasses, trees, shrubs and some of the vegetables require light to obtain complete germination. In general, freshly harvested seeds are more sensitive to light than "aged" seeds.

Both light intensity (candle-power) and light quality (color or wave length) influence germination. The Rules specify a light intensity of 75-125 foot candles (i.e. 750-1250 lux) for the germination of dormant seeds.

Where prescribed in the AOSA Rules for Testing Seeds, light should be provided by a cool white fluorescent or LED (Light-Emitting Diode) source, for at least eight hours in every 24. Those species requiring light should be germinated on the top of the substratum. When an alternation of temperature is used, seeds should be illuminated during the high temperature period. Although light is prescribed for some species, no distinction is made between dormant and non-dormant seeds within these species. Illumination of non-dormant seeds is generally beneficial (except for those inhibited by light) since the seedlings become green and the essential structures are easier to evaluate. One caution is needed since lights produce heat: The germination analyst should make certain the temperature at the substratum level never exceeds the prescribed temperature. (See section 6.9 f of the AOSA Rules for Testing Seeds Vol. 1.)

3.5.3 Counting seedlings of multiple seed units and coated seeds. Seed units containing more than one true seed, e.g. beet clusters (*Beta vulgaris*), New Zealand spinach (*Tetragonia tetragonoides*) or multiple florets of certain grasses (e.g. *Dactylis glomerata*), are tested as single seeds and are classed as normal if at least one seedling develops and continues to grow under favorable conditions. When a seed unit (i.e. a single cluster or multiple floret) produces two or more seedlings it is only counted as one seedling. (See section 6.5 c of the AOSA Rules for Testing Seeds Vol. 1.)

For coated seeds the seed units should be placed on the substratum in the condition in which they are received. No rinsing, soaking or other pre-treatment should be used. Each coated seed is considered a seed unit when counting the seedlings. If symptoms of phytotoxicity are evident on seedlings from coated seeds planted on artificial substrata, a retest should be conducted in sand or soil. (See section 6.8 l of the AOSA Rules for Testing Seeds Vol. 1.)

For specific instructions on de-coating Poaceae seed kinds, see section 6.8 l of the AOSA Rules for Testing Seeds Vol. 1. If coated seed is received with a request for a test on de-coated seed, then the germination report should include specific information about the procedure used.

3.5.4 Hard, swollen, dormant and dead seeds. Hard seeds are seeds that remain hard at the end of the prescribed test period because they have not absorbed water due to an impermeable seed coat. Species known to produce hard seeds are indicated by footnotes in Table 6A of the AOSA Rules for Testing Seeds Vol. 1. The percentage of hard seeds occurring in the germination test will vary with the age, kind, variety and moisture content of the seed. The hard seed content of some freshly harvested legumes such as red clover, lespedeza and field peas may decrease rapidly within the first few weeks or months of dry laboratory storage. Conversely, seeds of okra, vetch and certain other legumes may increase in hard seed content during dry laboratory storage. The hard seededness in beans is increased as the beans become desiccated. The relative humidity of the air in the storage area may cause moisture changes within the seeds and hence changes in the number of hard seeds. These changes are reversible. In reporting the test results, the percentage of hard seeds is reported in addition to the percentage germination.

Swollen seeds are seeds that have imbibed water but have not germinated; they may or may not be visibly larger than seeds that have not imbibed water. Swollen seeds may or may not be viable. They may be observed in germination tests of some species of the Fabaceae, Convolvulaceae, Geraniaceae and Malvaceae. Often a somewhat lower germinator temperature will result in fewer swollen seeds and a higher germination percentage. If there is a question whether seeds are swollen or hard, slight tweezer pressure on the questionable seeds will provide the answer. Care should be used in pressing to avoid damage to swollen seeds. If at the end of the regular germination period for species in the four families above, there remain swollen seeds or seeds that have just started to germinate, remove all fully developed seedlings, abnormal seedlings, hard seeds, and dead seeds. Extend the test five more days (except that for flat pea *Lathyrus sylvestris*, extend the test 14 days at 15-25°C or 10 days at 20°C). After the prescribed number of additional days, any additional normal seedlings should be included in the percentage germination. Further information concerning procedures related to swollen and hard seeds is provided in sections 6.8 a, 6.9 d (6), 6.9 m (3) and 6.9 m (6) of the AOSA Rules for Testing Seeds Vol. 1.

Dormant seeds are viable seeds that fail to germinate when provided with suitable germination conditions as specified in Table 6A of the AOSA Rules for Testing Seeds Vol. 1. All samples suspected of having dormant seeds should be tested under conditions suitable for breaking dormancy, as described in section 6.8 and under "Specific requirements and notes" and "Fresh and dormant seed" of Table 6A of the AOSA Rules for Testing Seeds Vol. 1. However, even when appropriate procedures are used, the germination analyst must sometimes distinguish between hard, dormant and dead seeds. Often if there are dead seeds in a sample they become evident after a few days in test. Dead seeds usually begin to decay, become soft, discolored and covered by fungi and bacteria. Dead seeds should be removed from the test to avoid further contamination of the substratum, seedlings and other seeds. Dormant seeds usually remain relatively free of fungi; however, dormant grass florets often become covered by mold and therefore the presence of fungi alone should not be considered as evidence that florets are non-viable.

Viability of ungerminated seeds which remain at the end of the prescribed test period may be determined by any appropriate method or combination of methods given in section 6.9 m of the AOSA Rules for Testing Seeds Vol. 1. The percentage of dormant seeds may be reported in addition to the percentage germination.

3.5.5 Diseased and decayed seedlings. Primary infection originates from the seed or seedling itself. Seedlings with slight primary infection are considered normal provided development of none of the essential structures has been impaired. Seedlings with primary infection sufficient to impede development of one or more essential structures are to be classified as abnormal.

Secondary infection is infection that does not originate with the seed itself, but rather from other diseased seeds, seedlings or adhering structures (such as the cluster of *Beta*). Decay caused by the spread of infection from the surface of adhering seed coats should be considered secondary. Seedlings with any degree of secondary infection are to be classified as normal provided that all essential structures are present and otherwise normal.

When decay is present in a test, counts should be made at approximately two-day intervals between the first and final counts, with obviously dead and moldy seeds being removed and recorded at each count. Samples should be retested if infection is extensive enough to make accurate evaluation difficult, or if improper test conditions may have contributed to the development of the infection.

Practices to minimize spread of mold include wider spacing of seeds, proper temperature control, removal of decayed seeds, adequate aeration and keeping the tests as dry as possible while providing adequate moisture for germination. Retesting in sand or soil will usually reduce the level of secondary infection. (See sections 6.5 a and 6.6 c (3) of the AOSA Rules for Testing Seeds Vol. 1.)

3.5.6 Negative geotropism. Negative geotropism is caused by a physiological disorder usually characterized by root structures that grow upward. Seedlings with negative geotropism must be classified as abnormal. However, the germination analyst must make certain that the condition is not caused by poor laboratory conditions. "Apparent" negative geotropism may occur with artificial substrata if adverse moisture conditions are present or if the substrata contain phytotoxic substances. Also, if seeds are planted in tightly packed soil or if the soil surface becomes dry, seedlings may appear to have negative geotropism. If test conditions are suspected to be the cause of negative geotropism, the sample should be retested under favorable conditions, including retests made in sand or soil.

3.5.7 Use of sand or soil. Sand, soil or a sand/soil mixture should be used in a retest whenever difficulty is experienced in judging essential seedling structures. These media provide the following advantages over artificial substrata:

a. Seedlings develop in an environment resembling field conditions. The seedlings appear more natural, therefore the analyst is more likely to correctly evaluate seedlings.

b. Sand and soil are less favorable environments for the growth of saprophytic fungi and bacteria that often proliferate unchecked on artificial substrata. Also, these organisms may be controlled by competition with fungi and bacteria that occur naturally in the soil (if it is non-sterile).

c. Absorption of phytotoxic substances by the soil will often reduce the severity of chemical seed treatment. The soil may also neutralize natural seed inhibitors.

d. The ability of roots to anchor seedlings in sand or soil makes it possible to grow seedlings to a later stage of development than on artificial substrata; this permits observation of the continued development of questionable seedlings.

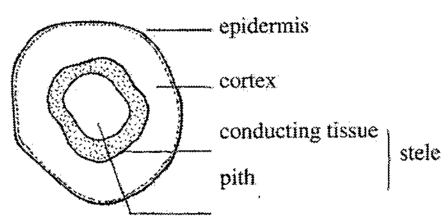
Germination analysts should become familiar with the appearance of seedlings of all species when grown in sand or soil so they can evaluate seedlings correctly when they are grown on artificial substrata. Simultaneous tests on artificial substrata and in sand or soil are particularly helpful. (See sections 6.3, 6.5 b (1), 6.6 c and d, and 6.8 l (3) of the AOSA Rules for Testing Seeds Vol. 1.)

3.5.8 The fifty percent rule. Unless otherwise stated in the seedling descriptions, seedlings are to be classified as abnormal if less than 50 percent of their cotyledonary tissue remains attached or free of decay. Notable exceptions to this rule are identified in the following section related to large-seeded epigeal Fabaceae, for which the cotyledons may be missing provided the seedling is otherwise normal and vigorous.

3.5.9 Lesions in dicotyledonous species. In seedlings of dicotyledons the root-shoot axis is made up of a central stele (or cylinder), surrounded by cortex and epidermis. The conducting tissues are in a concentric ring forming the outer layers of the stele, and serve to transport water and nutrients. In the seedling descriptions, deep open cracks extending into the conducting tissue of the hypocotyl or epicotyl are considered to be abnormalities, for two reasons: (a) interference with movement of water and nutrients through the affected area, and (b) increased susceptibility of the seedling to micro-organism attack.

The location of the conducting tissue (i.e. distance from the surface) may vary between species and it is not readily visible without magnification. Therefore, it is strongly recommended that some time be spent observing hypocotyl and epicotyl cross-sections under the microscope. It is particularly useful to observe various types of lesions in cross section, in order to get a "feel" for the link between the appearance of the lesion and its severity.

The following drawings of a soybean hypocotyl cross section illustrate the severity of lesion depth (Fig. 3.1). Note that this guideline cannot be applied to monocots, because in monocots the vascular bundles are not in a clearly defined concentric ring, but are scattered.



soybean hypocotyl cross-section

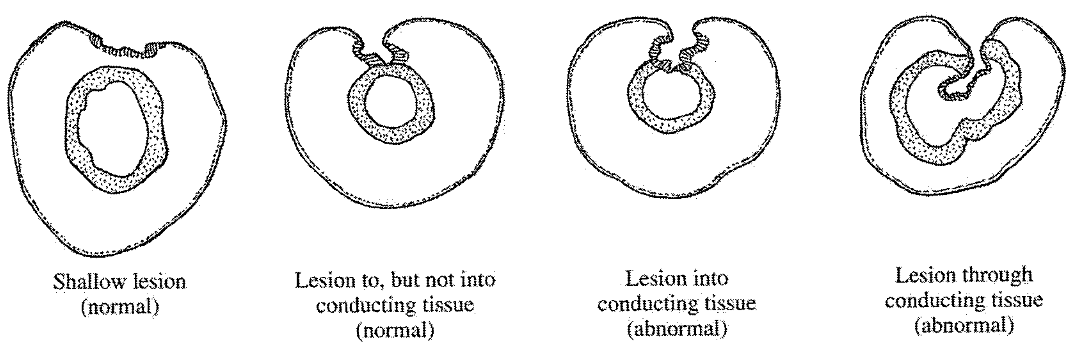


Fig. 3.1 Depth of lesions.

3.5.10 Decay at the point of attachment of the cotyledons and terminal bud decay. Seedlings exhibiting decay at the point of attachment of the cotyledons to the seedling and/or decay (that was not caused by test conditions) in and around the terminal bud, causes the seedling to be classified as abnormal. The 50% Rule (see section 3.5.8) does not apply when either of these conditions is present.

PART II. SEEDLING DESCRIPTIONS

In general, the following are considered to be essential structures necessary for the continued development of the seedling (although some structures may not be visible in all species at the time of seedling evaluation).

- root system, consisting of primary and/or secondary, seminal or adventitious roots
- hypocotyl
- epicotyl
- cotyledon(s)
- terminal bud
- primary leaves

Seedlings with defects to these structures, as described in the abnormal seedling descriptions, are judged to be incapable of continued growth.

The detailed seedling descriptions are given in the following sections. These descriptions assume that test conditions were adequate to allow proper assessment of the essential seedling structures. If it is suspected that the test conditions have contributed to seedling abnormalities or the spread of infection to the point where evaluation is difficult, the sample should be retested under more favorable conditions.

The "General Description" for each group of crop kinds describes a seedling without defects, accompanied by a labeled drawing of a "typical" seedling. While such a seedling is clearly normal, seedlings with some defects may also be classified as normal, provided the defects do not impair the functioning of the structure. The "Abnormal Seedling Description" is to be followed when judging the severity of defects.

The descriptions are accompanied by drawings of normal (+) and abnormal (-) seedlings. Each drawing has a caption describing the important characteristic(s) of the seedling. If no + or - designation is given with a drawing, read the caption for that drawing.

The drawings are intended to illustrate "typical" normal and abnormal seedlings as a supplement to the written descriptions; they do not cover the full possible range of abnormalities that may be observed. They are not intended to replace the descriptions, nor are they intended to be used as a template for direct overlay of seedlings.

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AIZOACEAE, CARPETWEED FAMILY

Tetragonia tetragonoides, New Zealand spinach

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Leaf-like cotyledons and perisperm.

Shoot system: The hypocotyl elongates carrying the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A primary root; secondary roots may develop within the test period.

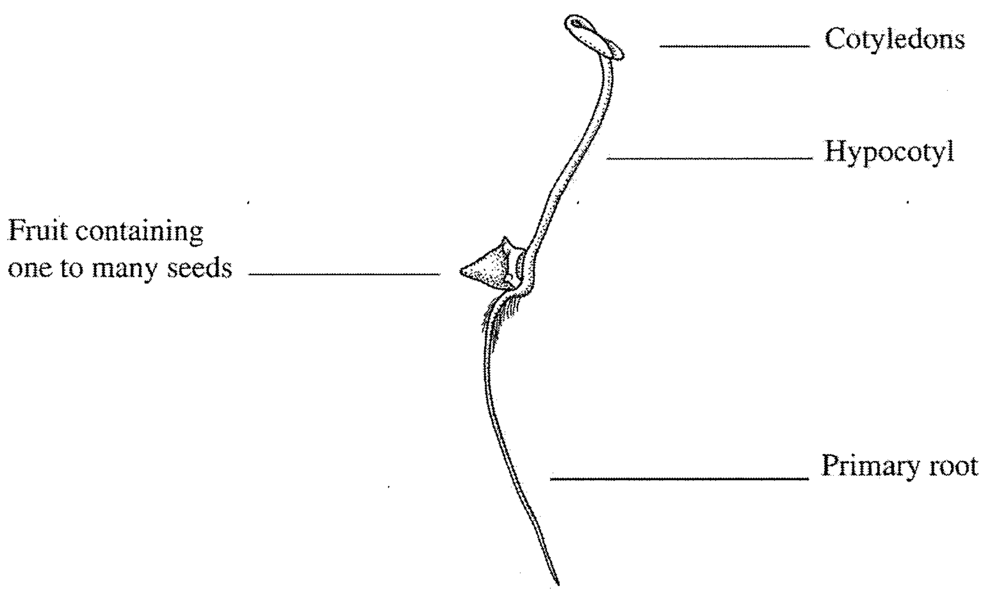


Fig. 1 New Zealand Spinach.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

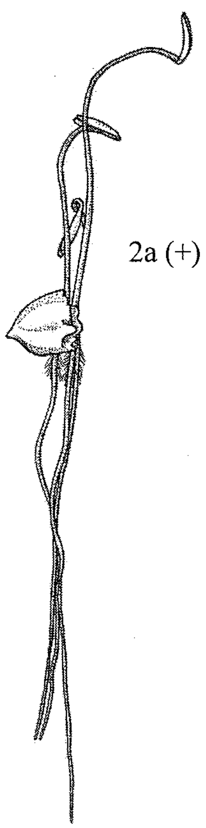
Epicotyl:
- missing (may be assumed to be present if cotyledons are intact).

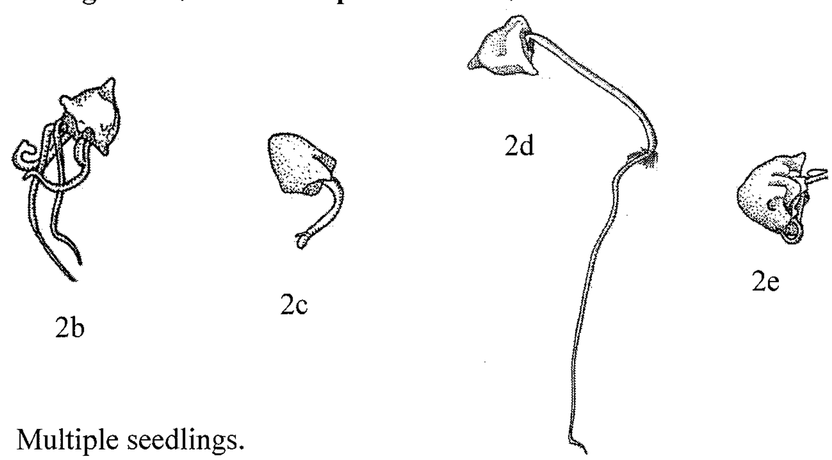
Hypocotyl:
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.
- watery.

Root:
- none.
- weak, stubby or missing primary root with weak secondary or adventitious roots.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

Fig. 2 New Zealand Spinach.





2a. Multiple seedlings.

2b. Multiple seedlings at early stage of development. Two seedlings developing normally, two abnormally. Continue test until structures can be fully evaluated.

2c. Stunted root. Abnormal at final count; continue test a earlier counts.

2d. Embedded cotyledons. Normal after confirming cotyledons are normal.

2e. Seedlings just emerging. Continue or extend test until structures can be fully evaluated.

APIACEAE, CARROT FAMILY

Anethum graveolens, dill
Anthriscus cerefolium, chervil
Apium graveolens, celery and celeriac
Carum carvi, caraway
Coriandrum sativum, coriander
Cuminum cyminum, cumin
Daucus carota subsp. *carota,* Queen Anne's lace
Daucus carota subsp. *sativus,* carrot
Foeniculum vulgare, fennel
Pastinaca sativa, parsnip
Petroselinum crispum, parsley
Pimpinella anisum, anise

Trachymene coerulea [Araliaceae], blue lace flower

GENERAL DESCRIPTION

Seeding type: Epigeal dicot.

Food reserves: Endosperm that is fleshy and firm; long, narrow cotyledons that become leaf-like and photosynthetic.

Shoot system: The hypocotyl elongates and carries the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A long, slender primary root.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:
- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl:
- decayed at point of attachment.
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.
- watery.

Root:
- weak, stubby or missing primary root (secondary roots will not compensate for a defective primary root).

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. Seed units in the Apiaceae may be schizocarps (two-seeded) or mericarps (one-seeded). Frequent counts should be made on schizocarps, since growing seedlings will separate. Any schizocarp that produces at least one normal seedling is classified as normal; only one seedling per schizocarp is to be counted.

REFERENCES

Wellington, P.S. 1970. Evaluation of seedlings of the Umbelliferae. Proc. Int. Seed Test. Ass. Vol. 35(2):591-597.

ASTERACEAE, SUNFLOWER FAMILY I - Lettuce

Lactuca sativa, lettuce

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons that expand and become thin, leaf-like and photosynthetic. Some varieties develop elongated petioles at the base of the cotyledons.

Shoot system: The hypocotyl elongates and carries the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A long primary root.

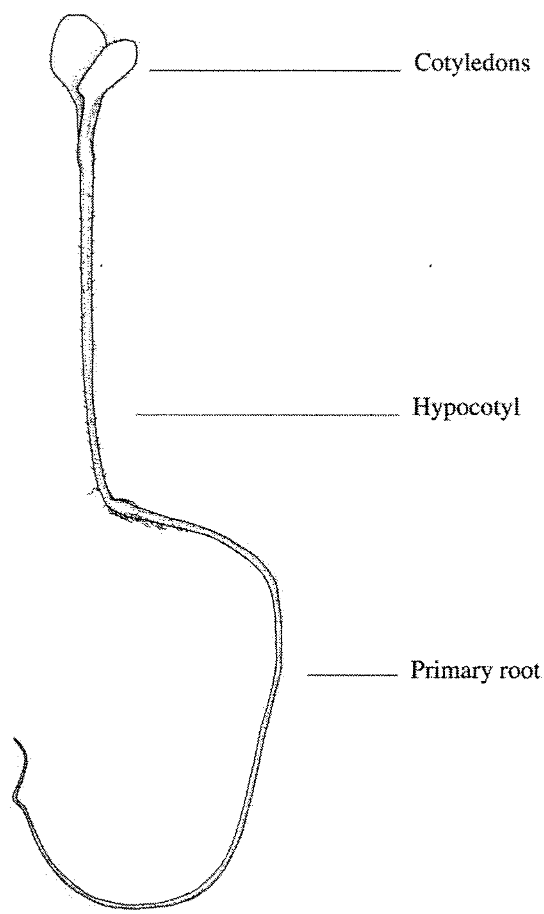


Fig. 1 Lettuce.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons

- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay (see notes 5 and 6).
- cotyledons that are swollen, curled, deformed.

Epicotyl

- missing (may be assumed to be present if cotyledons are intact).
- any degree of necrosis or decay.

Hypocotyl

- deep open cracks extending into the conducting tissue.
- severely twisted or grainy.
- watery.
- malformed, such as markedly shortened, curled or thickened.

Root

- none.
- primary root tip blunt, swollen and discolored.
- primary root with splits or lesions.
- weak, stubby or missing primary root (secondary roots will not compensate for a defective primary root).

Seedling

- swollen cotyledons associated with extremely short or vestigial hypocotyl and root.
- one or more essential structures impaired as a result of decay from primary infection.
- albino or yellow.

NOTES

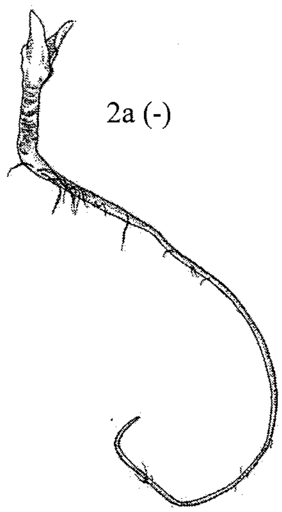
1. Toxic materials in the substrate will cause short, blunt roots. The roots lift away from the substrate. Check media for toxicity. Conduct retest if necessary on alternate approved media.
2. Seedlings grown on top of white filter paper will be shorter than those grown on colored blotters. Retest if necessary.
3. Remove attached seed coats for seedling evaluation.
4. Seedlings with slight dormancy or light sensitivity may be slow to germinate. Extend test according to the Rules.
5. One type of necrosis on lettuce cotyledons is a physiological breakdown of the plant tissues, the cause of which has not been determined. It is manifested by discolored areas on the cotyledons, first appearing on or adjacent to the midrib and lateral veins, and should not be confused with the natural pigmentation of the different lettuce cultivars.
6. Seedlings with extensive physiological necrosis on the cotyledons may be slower in growth than those without such affected areas. Hypocotyl and root length may be affected by other factors such as proximity to light, delayed germination or dormancy.
7. Seedlings with three cotyledons should be considered as normal.
8. The 50% rule must be followed to classify seedlings with damaged cotyledons (dark areas of discoloration or decay) as either normal or abnormal.

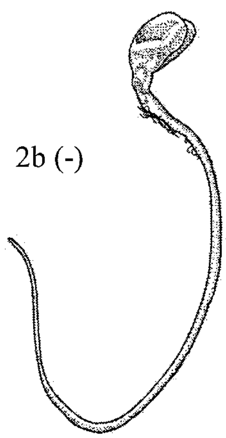
2a. Grainy hypocotyl.

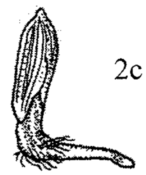
2b. Shortened hypocotyl.

2c. No hypocotyl development, stubby root.

2d. Physiological necrosis. See Figure 3.







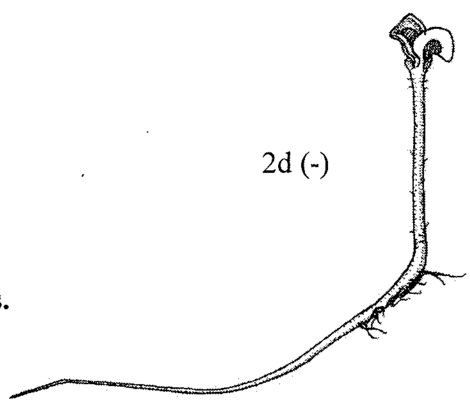
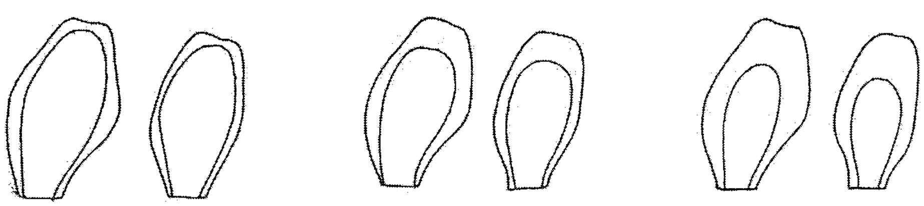


Fig. 2 Seedling defects.

Fig. 3 Physiological necrosis of lettuce cotyledons.



3a (-) 3b (-) 3c (+)

3a. Cotyledons 65% necrotic.

3b. Cotyledons 50% necrotic.

3c. Cotyledons 35% necrotic.

ASTERACEAE, SUNFLOWER FAMILY II - Kinds other than lettuce

Arctium lappa, great burdock
Artemisia ludoviciana, Louisiana sagewort
Carthamus tinctorius, safflower
Cichorium endivia, endive
Cichorium intybus, chicory
Cynara cardunculus, cardoon
Cynara cardunculus, artichoke
Helianthus annuus, sunflower
Taraxacum officinale, dandelion
Tragopogon porrifolius, salsify

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons that expand and become thin, leaf-like and photosynthetic.

Shoot system: The hypocotyl elongates and carries the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A long primary root with secondary roots usually developing within the test period.

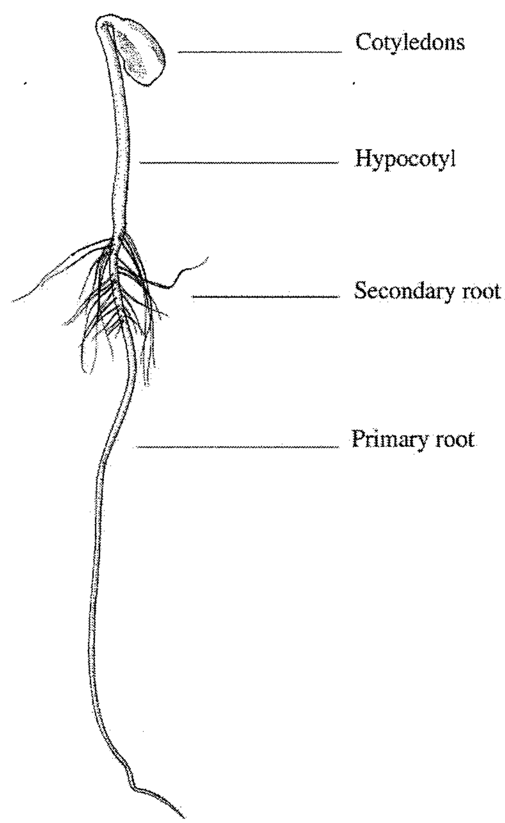


Fig. 1 Sunflower.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay (see note 7).

Epicotyl
- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl
- decayed at point of attachment.
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.
- watery.

Root
- none.
- weak, stubby or missing primary root with weak secondary or adventitious roots (see notes 1 and 5).

Seedling
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES
1. Substrate with insufficient moisture may result in slow or abnormal development, bound roots, retarded secondary root development or unshed seed coats.

2. Some seed lots of sunflower will exhibit dormancy if the substrate is on the wet side.

3. Due to the thick, dry seed coat, imbibition may be slow and the subsequent germination erratic. Some seeds may just be starting at the end of the test period and it may be necessary to extend the test as allowed under Sec. 6.9 d (4) of the AOSA Rules Vol. 1.

4. All seeds in this group may exhibit some dormancy and a retest using appropriate dormancy breaking procedures may be necessary.

5. Frequently the root may become bound within the hard seed coat. If left in the test until the final count such seedlings may develop secondary roots sufficient to be considered normal. Bound roots are usually not a problem in soil tests since the secondary root development is faster than in artificial media.

6. The hypocotyl may be slow to develop in seedlings with a damaged primary root.

7. Seedlings with unshed seed coats may have decayed cotyledons. The seed coat must be removed for evaluation.

8. For dormant samples of endive, add about 1/8 inch of water at the beginning of the test and remove excess water after 24 hours.

Fig. 2 Root defects.

2a. Normal seedling.

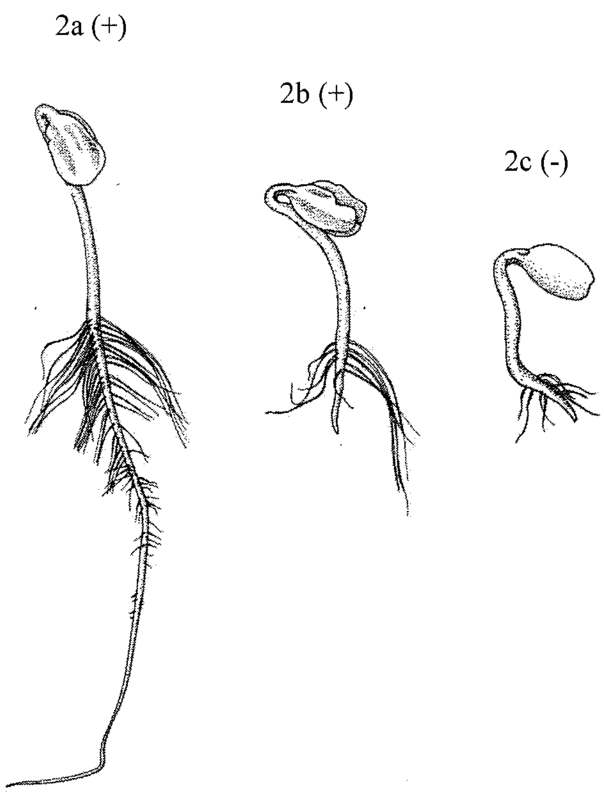
2b. Stubby primary root, sufficient secondary roots.

2c. Stubby primary root, insufficient secondary roots.

Fig. 3 Hypocotyl defects.

3a. Deep hypocotyl lesion (see 3.5.9).

3b. Primary infection of hypocotyl.



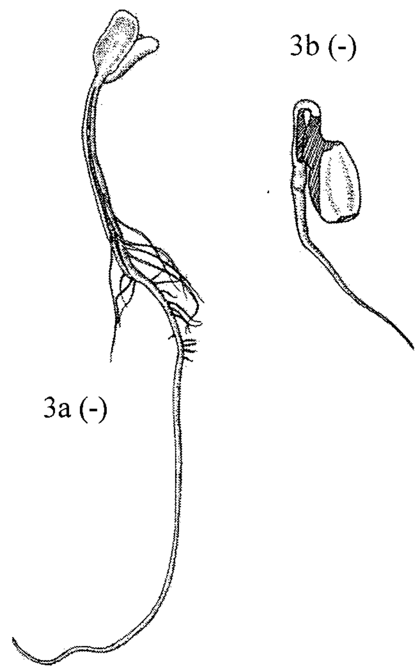
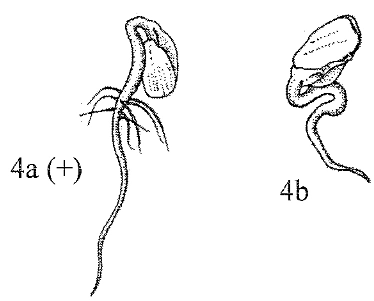


Fig. 4 Small seedlings.

4a. Late-germinating seedling (at final count; see 3.5.1.b).

4b. Seedling too small to evaluate; extend test (see 3.5.1.b).



BALSAMINACEAE, BALSAM FAMILY

Impatiens balsamina, balsam
Impatiens walleriana, impatiens

GENERAL DESCRIPTION

Seeding type: Epigeal dicot.

Food reserves: Cotyledons that expand and become photosynthetic.

Shoot system: The hypocotyl elongates carrying the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A primary root, with one to many secondary roots, which usually develop within the test period. The primary root is not always readily distinguishable from the secondary roots.

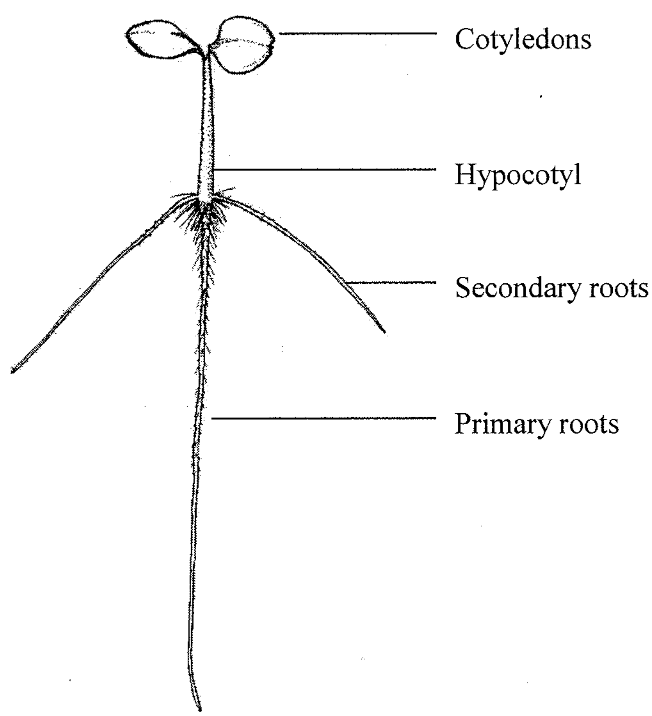


Fig. 1 Impatiens.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.
- curled, thickened or cupped, less than half normal size.

Epicotyl:
- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl:
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.
- watery.

Root:
- none.
- weak, stubby or missing primary root with less than two strong secondary roots.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

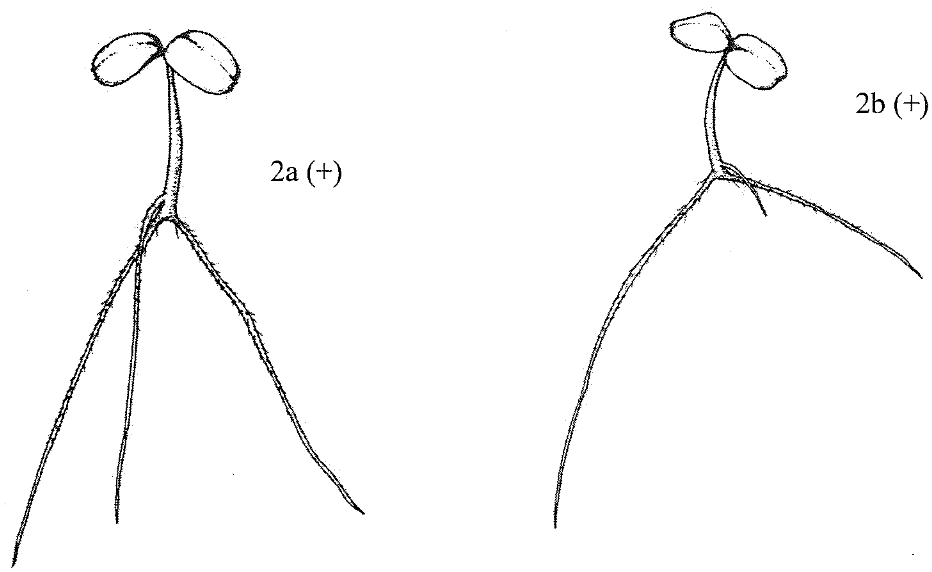
1. Some color forms will be dormant in temperatures above constant 27°C.

2. *Impatiens* seeds may exhibit some dormancy. Appropriate dormancy breaking procedures may be necessary. KNO_3 and prechill at 5°C are recommended for breaking dormancy.

3. Some *Impatiens* seem to develop multiple secondary roots in the initial growth period while others seem to have a predominately long primary root with secondary roots developing later. Both are normal growth patterns.

4. *Impatiens balsamina,* balsam, usually has multiple secondary roots during the initial growth period.

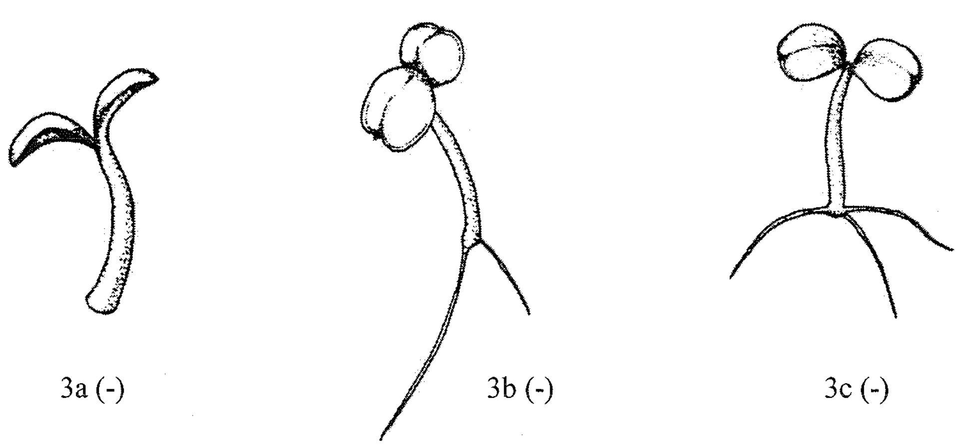
Fig. 2 Root defects (normal).



2a. Primary root missing, three strong secondary roots.

2b. Primary root missing, two strong secondary roots.

Fig. 3 Root defects (abnormal).

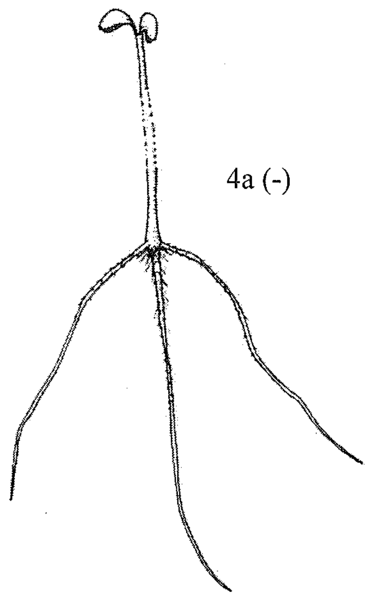


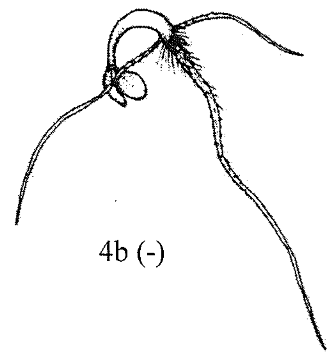
3a. Root missing.

3b. Primary root missing with less than two strong secondary roots.

3c. Primary root missing, insufficient secondary roots.

Fig. 4 Cotyledon and hypocotyl defects.





4a. Cotyledons curled, thickened and cupped, less than half normal size. Hypocotyl watery.

4b. Hypocotyl malformed, markedly shortened and curled.

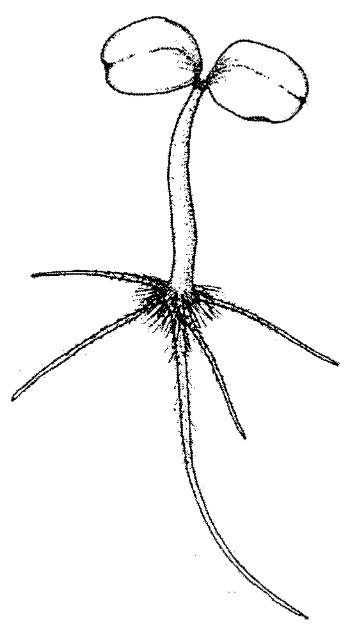


Fig. 5 *Impatiens balsamina*, balsam, with multiple secondary roots.

BRASSICACEAE, MUSTARD FAMILY

Barbarea verna, upland cress
Brassica spp., mustards etc.
Crambe hispanica subsp. *abyssinica*, crambe
Eruca versicaria subsp. *sativa*, roquette
Lepidium sativum, garden cress
Nasturtium officinale, watercress
Raphanus sativus, radish
Sinapis alba, white mustard

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons that expand and become thin, leaf-like and photosynthetic. In *Brassica*, *Sinapis* and *Raphanus*, the cotyledons are bi-lobed and folded, with the outer cotyledon being larger than the inner.

Shoot system: The hypocotyl elongates and carries the cotyledons above the soil surface; the epicotyl usually does not show any development within the test period.

Root system: A long primary root.

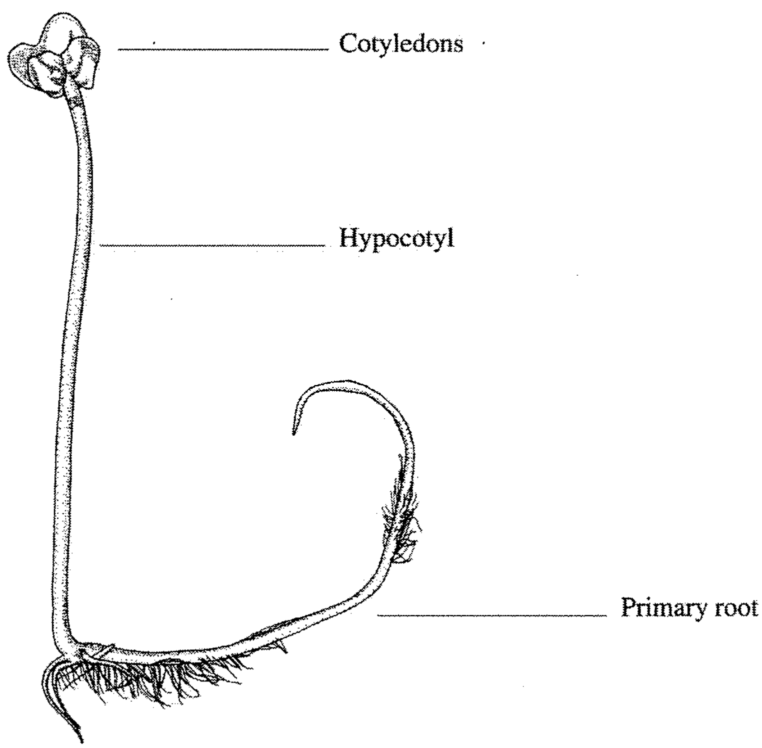


Fig. 1 ***Brassica.***

ABNORMAL SEEDLING DESCRIPTION

Cotyledons

- decayed at point of attachment.
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl

- missing (may be assumed to be present if the cotyledons are intact).

Hypocotyl

- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.
- watery.

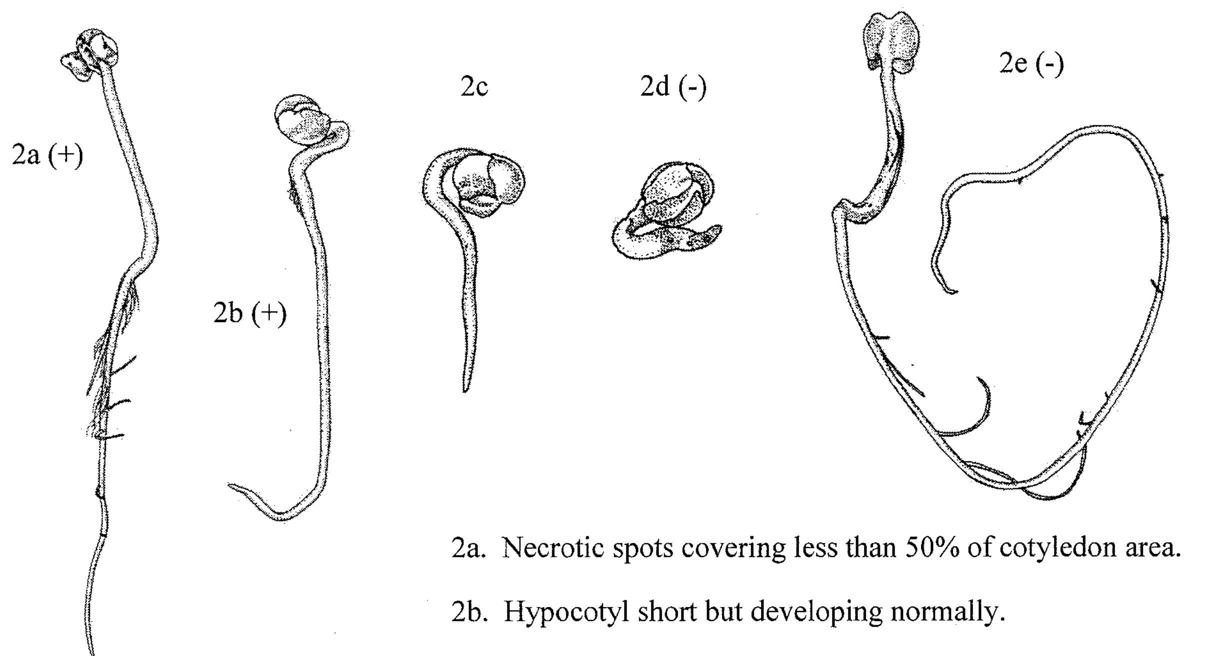
Root

- weak, stubby or missing primary root (secondary roots will not compensate for a defective primary root).

Seedling

- one or more essential structures impaired as a result of decay from primary infection
- albino.

Fig. 2 *Brassica.*



2a. Necrotic spots covering less than 50% of cotyledon area.

2b. Hypocotyl short but developing normally.

2c. Seedling too small to evaluate; extend test (see sec 3.5.1.b).

2d. Stubby primary root, poor hypocotyl development.

2e. Hypocotyl lesions.

CARYOPHYLLACEAE, PINK FAMILY

Cerastium tomentosum, snow-in-summer
Dianthus ×allwoodii, sweet wivelsfield
Dianthus barbatus, sweet-william
Dianthus caryophyllus, carnation
Dianthus chinensis, China pinks
Dianthus deltoides, maiden pinks
Dianthus plumarius, grass pinks
Gypsophila elegans, long-petaled baby's-breath
Gypsophila pacifica, Pacific baby's-breath
Gypsophila paniculata, perennial baby's-breath
Gypsophila repens, baby's-breath
Sagina subulata, pearlwort
Saponaria ocymoides, rock saponaria
Silene armeria, sweet-William catchfly
Silene chalcedonica, Jerusalem-cross
Silene coronaria, rose campion
Silene viscaria, clammy campion
Vaccaria hispanica, cow-cockle

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Leaf-like cotyledons and perisperm.

Shoot system: The hypocotyl elongates and carries the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A primary root; root hairs may develop within the test period.

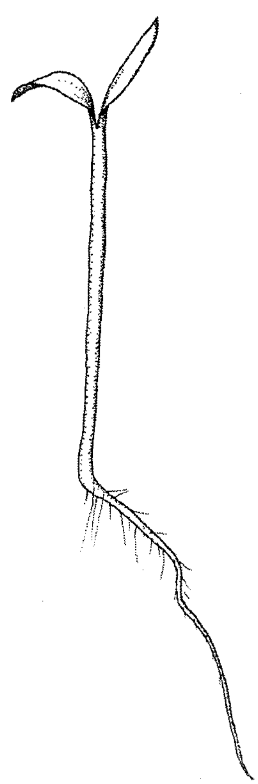


Fig. 1 *Dianthus*.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- Less than half of the original cotyledon tissue remaining attached (see note 1).
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:
- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl:
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened (see note 2).
- watery (see note 5).

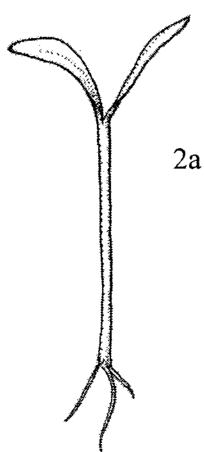
Root:
- weak, stubby or missing primary root; secondary roots will not compensate for a defective primary root (see note 3).

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

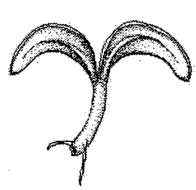
NOTES

1. In certain species (e.g. *Dianthus*), the seedling may produce three cotyledons instead of two. This should be considered normal as long as the seedling is otherwise normal.
2. The hypocotyl may show minor twisting due to processing damage. If not too severe, such a seedling would be considered to be normal.
3. For *Dianthus* spp., older seed lots may show declining vigor, which is indicated by shortened roots and/or hypocotyl. These seedlings would be considered normal as long as the growth is proportional and adequate to support the seedling.
4. In *Dianthus* spp., there may be a lot of mechanical damage, leading to abnormal seedlings. Cotyledons may become caught up in the seed coat; it is important to remove the seed coat for evaluation of the cotyledons that may be broken due to the mechanical damage.
5. In some species (e.g. *Dianthus*), problems with watery hypocotyls may occur if test conditions are too wet.

Fig. 2 Root defects (abnormal).



2a (-)

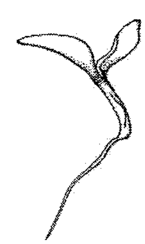


2b (-)

2a. and b. Primary root stubby or missing; secondary root will not compensate.

Fig. 3 Hypocotyl defects (abnormal).

3a (-)



3b (-)

3a. Hypocotyl watery.
3b. Hypocotyl markedly shortened with deep open cracks.

CHENOPODIACEAE, GOOSEFOOT FAMILY

Beta vulgaris, beet, sugar beet, mangel, Swiss chard
Bassia prostrata, forage kochia
Spinacia oleracea, spinach

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Leaf-like cotyledons and perisperm.

Shoot system: The hypocotyl elongates carrying the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A primary root; secondary roots may develop within the test period.

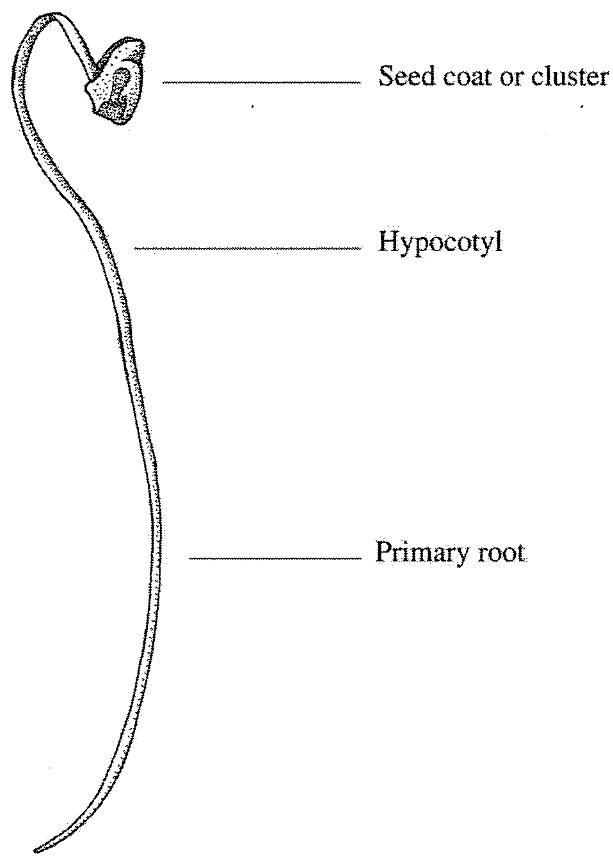


Fig. 1 Beet.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:
- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl:
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.
- watery.

Root:
- none.
- weak, stubby or missing primary root with weak secondary or adventitious roots.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection (for discolored seedlings of *Beta* spp., see note 2).
- albino.

NOTES

1. See AOSA Rules Vol. 1 Sec. 6.8 c for directions to wash samples of *Beta* prior to planting. Chemical inhibitors in the cluster or seed coat may work together with excess water to rob the embryo of oxygen and thus prevent germination. It is important, therefore, to ensure the seeds or clusters are dried before planting.

2. Toxic substances from the clusters of *Beta* may cause discoloring of the hypocotyl and/or root. Seedlings that are slightly discolored are to be classified as normal; however, if there is excessive discoloration, retest in soil or by washing in running water for 3 hours (see Sec. 6.8 c of the AOSA Rules Vol. 1).

3. Frequent counts should be made on multigerm beet since the growing seedlings will separate from the cluster making it difficult to identify its source. Any cluster that produces at least one normal seedling is classified as normal; only one normal seedling per cluster is to be counted.

Fig. 2

2a. Multiple seedlings.

2b. Seedling separated from cluster.

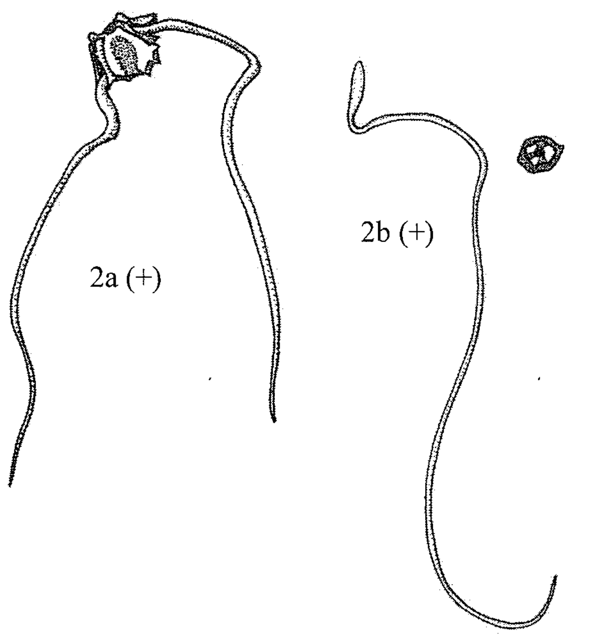
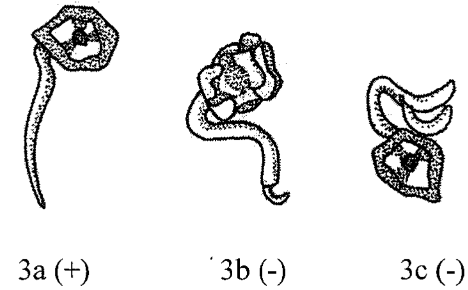


Fig. 3 Small seedlings.

3a. Late-germinating seedling (at final count; see sec 3.5.1.b.).

3b. Stubby root.

3c. No root development.



Note: Cotyledons must be examined.

CUCURBITACEAE, CUCURBIT FAMILY

Citrullus amarus, citron
Citrullus lanatus subsp. *lanatus*, watermelon
Cucumis melo, muskmelon or cantaloupe
Cucumis sativus, cucumber
Cucurbita spp., pumpkin and squash

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons that are large and fleshy; they expand, become photosynthetic and are usually persistent beyond the seedling stage.

Shoot system: The hypocotyl elongates and the cotyledons are pulled free of the seed coat, which often adheres to a peg-like appendage at the base of the hypocotyl. The epicotyl usually does not show any development within the test period.

Root system: A long primary root with numerous secondary roots.

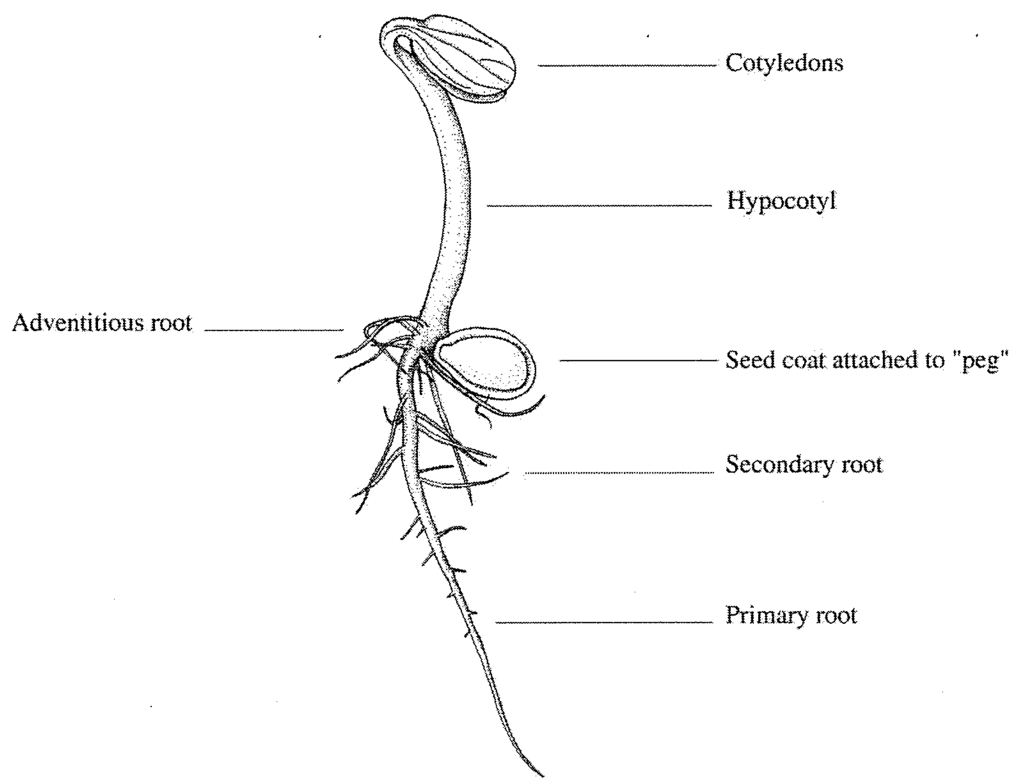


Fig. 1 Pumpkin.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay (see note 3).

Epicotyl:
- missing (can be assumed to be present if the cotyledons are intact).

Hypocotyl:
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened (see note 2).

Root:
- none.
- weak, stubby or missing primary root, with less than two strong secondary or adventitious roots.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. In general, seedling development is best when substrata are kept on the dry side. Extra moisture may then need to be added at the time of the first count.

2. Samples should be retested in sand or soil if there is evidence of chemical injury (characterized by badly thickened and shortened hypocotyls and roots). Seedlings showing chemical injury symptoms in the retest are to be classified as abnormal.

3. Seedlings with unshed seed coats may have decayed or damaged cotyledons. The seed coat must be removed for evaluation of the cotyledons.

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Thornton, M. 1968. Seed dormancy in watermelon *Citrullus vulgaris* Schrad. Proc. Assoc. Off. Seed Anal. 58:80-84.

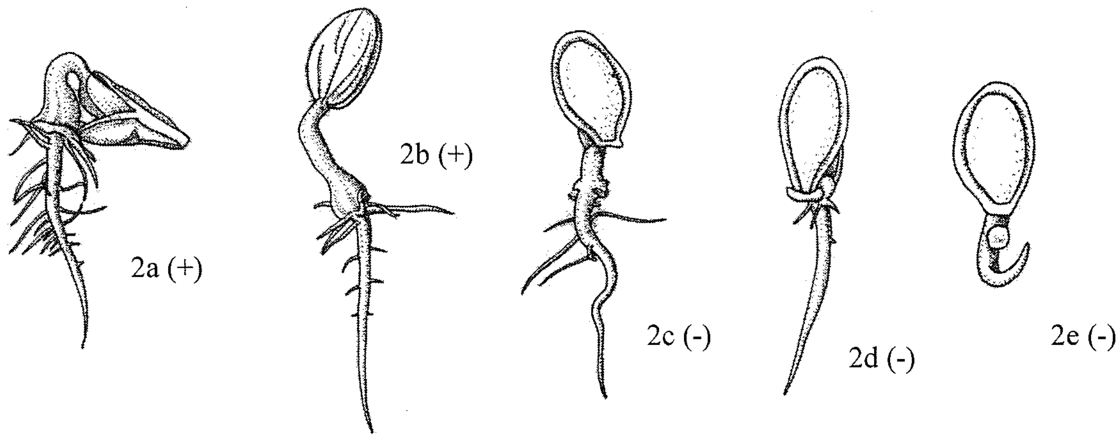


Fig. 2 Small seedlings.

2a. Late-germinating seedling (at final count; see 3.5.1.b.)

2b. Hypocotyl just long enough.

2c. Hypocotyl too short.

2d. No hypocotyl development.

2e. No hypocotyl, stubby root.

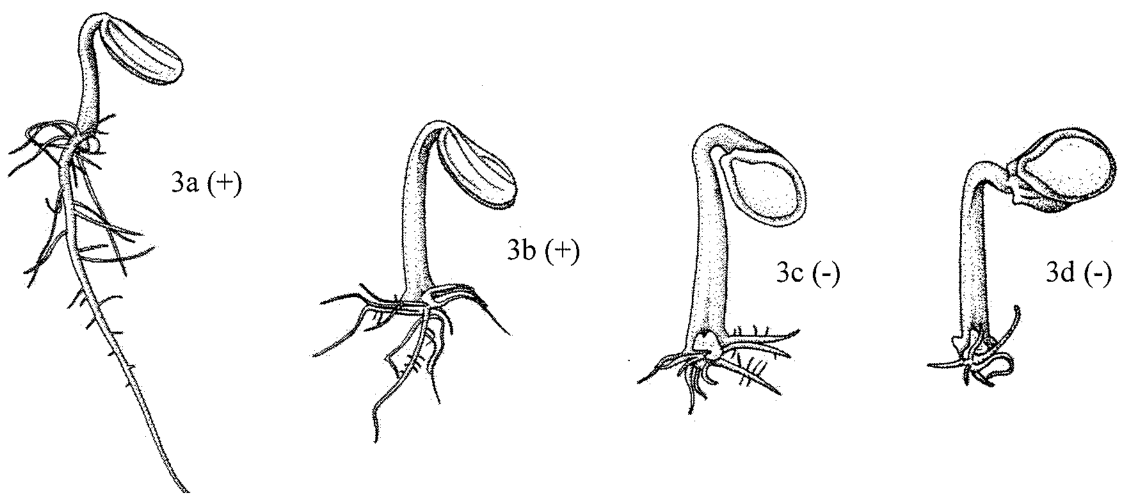


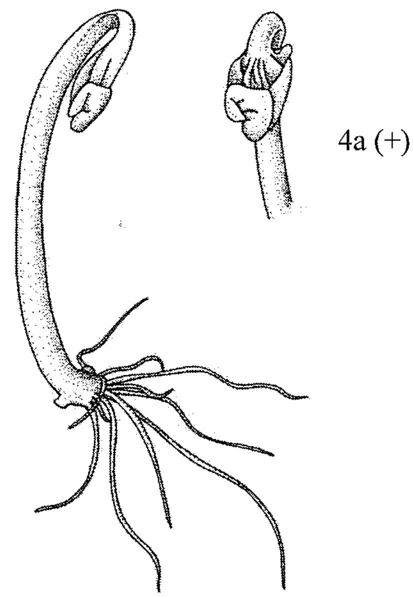
Fig. 3 Root defects.

3a. Normal development.

3b. Primary root missing or damaged, with sufficient secondary or adventitious roots.

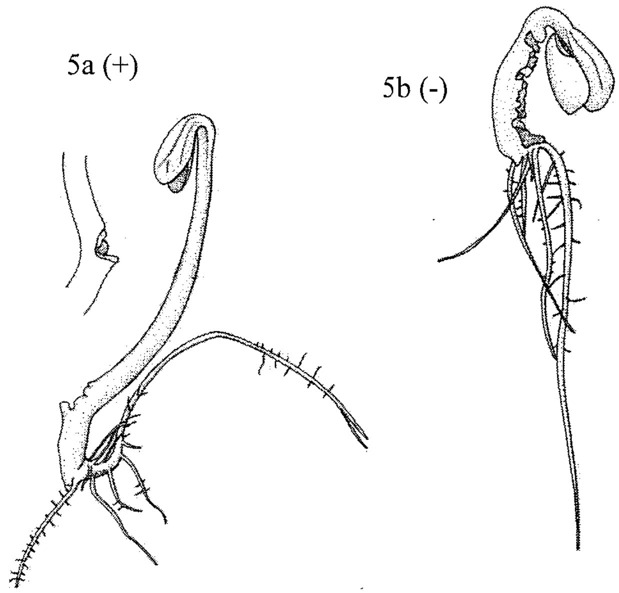
3c. Primary root missing or damaged, with insufficient secondary or adventitious roots.

3d. Insufficient roots.



4a. Cotyledons present but convoluted.

Fig. 4 Deformed cotyledons.



5a. Break caused by test conditions.

5b. Deep lesion.

Fig. 5 Hypocotyl lesions.

FABACEAE, LEGUME FAMILY I - Large-seeded epigeal, except soybean, peanut, lupine

Phaseolus lunatus, Lima bean
Phaseolus vulgaris, garden bean and field bean
Vigna radiata, mung bean
Vigna unguiculata subsp. *unguiculata*, cowpea, yard-long-bean

NOTE: For purposes of these rules, a garden bean (*Phaseolus vulgaris*) variety is defined as one that is grown for its fleshy pod to be eaten. Other beans, including field beans, are defined as those grown for their seeds to be eaten. Beans that are grown for either pod or seed to be eaten are to be considered garden beans, and the requirements for cotyledons apply (see abnormal seedling description).

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons that are large and fleshy; some photosynthesis may occur, but this is a minor function. They shrivel and drop off when the food reserves are depleted.

Shoot system: The hypocotyl elongates and carries the cotyledons above the soil surface. The epicotyl elongates causing the terminal bud to emerge from between the cotyledons; the primary leaves expand rapidly.

Root system: A long primary root with secondary roots.

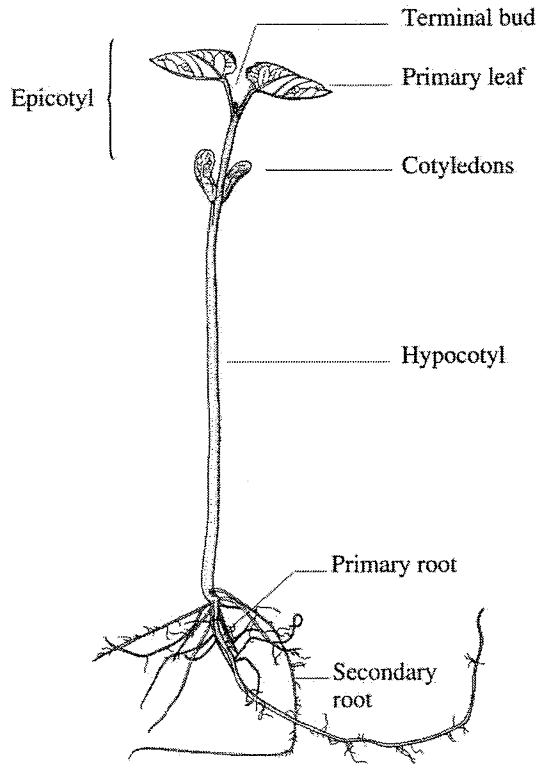


Fig. 1 Bean.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:

- garden bean (*Phaseolus vulgaris*, in part):
  -- less than half of the original cotyledon tissue remaining attached.
  -- less than half of the original cotyledon tissue free of necrosis or decay.
- all others:
  -- cotyledons are not assessed. EXCEPTION: If both cotyledons are missing and the seedling is generally weak, then the seedling is considered abnormal.

Epicotyl:

- missing.
- deep, open cracks.
- malformed, such as markedly curled or thickened.
- less than one primary leaf.
- primary leaves too small in proportion to the rest of the seedling, usually associated with visible defects of, or damage to, the main stem of the epicotyl.
- terminal bud missing or damaged (see note 8).

Hypocotyl:

- deep open cracks extending into the conducting tissue (see notes 1 and 6).
- malformed, such as markedly shortened, curled or thickened.
- (see also note 3.)

Root:

- none.
- weak, stubby or missing primary root with weak secondary or adventitious roots (see note 7).

Seedling:

- one or more essential structures impaired as the result of decay from primary infection (but see note 8).
- albino.

NOTES

1. Towels rolled too tightly may cause constriction of growing seedlings, resulting in malformation. Tight rolls, often in combination with a mid-test watering, may cause hypocotyl cracking or splitting.

2. Seeds of beans should be well spread out on or in the substrate. In general, the larger the seed, the more space it needs. Tightly concentrated seeds may compete to their detriment for water and for space to expand.

3. Hypocotyl collar rot is a breakdown in hypocotyl tissue characterized by "water-soaking" and collapse of the hypocotyl below the cotyledonary node. The lesion area later becomes discolored, shrivelled and necrotic. The condition is recognized as a laboratory phenomenon caused by insufficient calcium available to the seedling. If hypocotyl collar rot is observed

on seedlings of garden beans, the sample involved shall be retested using a 0.3 to 0.6 percent calcium nitrate solution to pre-soak the substratum (see Sec. 6.8 j of AOSA Rules Vol. 1).

4. The percentage of hard seeds is to be reported in addition to the percentage germination (see Sec. 6.2 d of the AOSA Rules).

5. If, at the end of the germination period, there are swollen seeds present, or seeds that have just started to germinate, remove everything but these seeds and continue the test. After five additional days, add any normal seedlings to the previous count. (See Sec. 6.9 d (6) and Sec. 6.9 m (6) of the AOSA Rules Vol. 1.)

6. A healed break in the hypocotyl, sometimes referred to as a "knee", is to be considered an allowable defect.

7. A seedling with the root bound within a tough seed coat is to be considered normal.

8. If a few seedlings with total or partial decay to the epicotyl are found, they may be classified as normal, provided the hypocotyl and root are normal. The epicotyl on such seedlings usually does not decay when grown in a fairly dry environment and is exposed to light. Retests, preferably in soil or sand, will aid in interpretation of such seedlings. For general instructions on evaluating seedlings infected with fungi or bacteria, see of Section 3.5.5 this handbook.

9. Large-seeded legumes are especially susceptible to threshing or combine damage. Seed that has been mechanically damaged may produce seedlings with damaged primary roots, hypocotyls or epicotyls, or broken or detached cotyledons. Bruised areas are usually necrotic or decayed. Damage at the point of attachment of the cotyledons may be difficult to evaluate if seedlings are removed too early in the test period.

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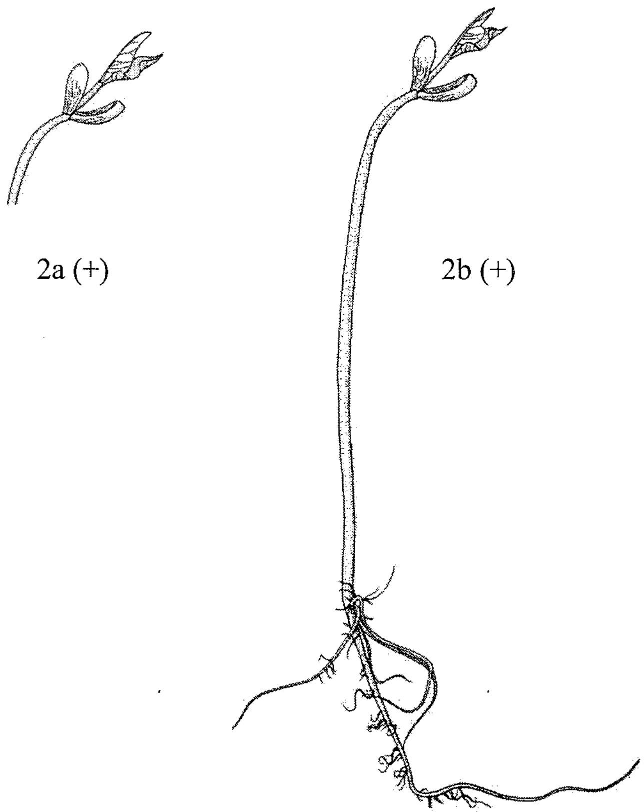


2c (-) 2d (-)

2a. Leaves large enough.

2b. Leaves large enough.

2c. Leaves borderline size, with damage to the epicotyl.

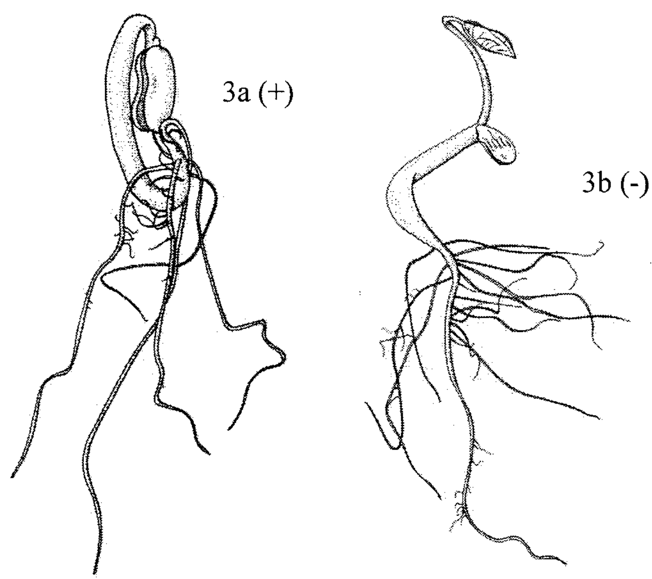
2d. Leaves too small.

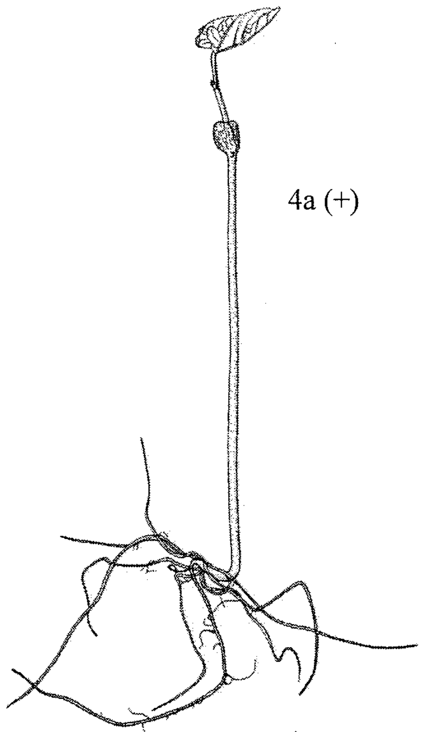
Fig. 2 Leaf size.

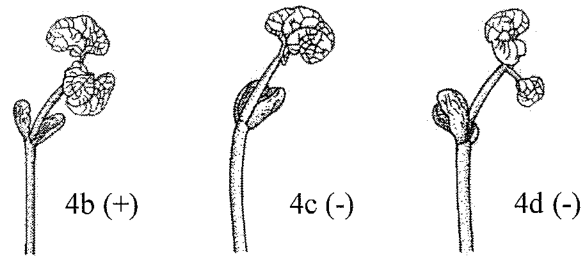
Fig. 3 Thickened hypocotyl.

3a. Hypocotyl thickened due to towel test.

3b. Hypocotyl thickened and short relative to epicotyl.







4a. One leaf missing, remaining leaf and terminal bud undamaged.

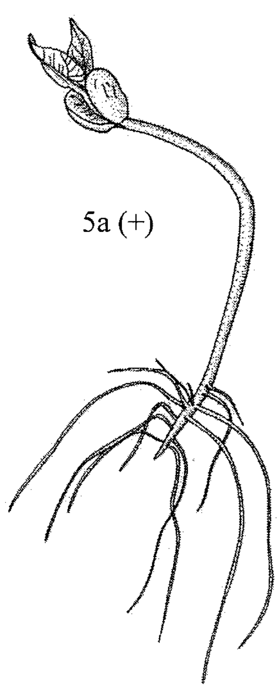
4b. Two leaves damaged but proportional in size to the rest of the seedling.

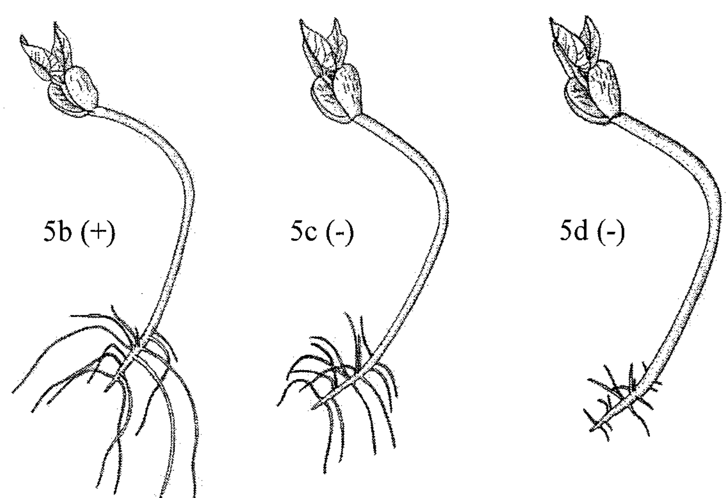
4c. One leaf missing, the remaining leaf damaged.

4d. Two leaves damaged and too small in proportion to the rest of the seedling.

Fig. 4 Damaged primary leaves.

Fig. 5 Root defects.





5a. Stubby primary root with sufficient secondary roots.
5b. Stubby primary root with sufficient secondary roots.
5c. Insufficient roots.
5d. Insufficient roots.

Fig. 6 Cotyledons, bean other than garden bean.

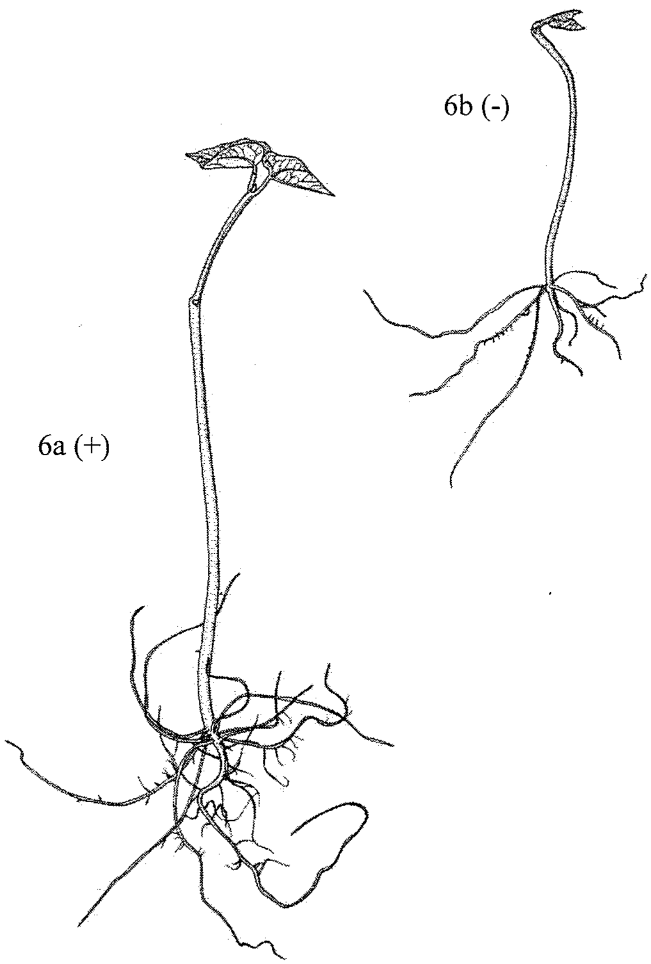
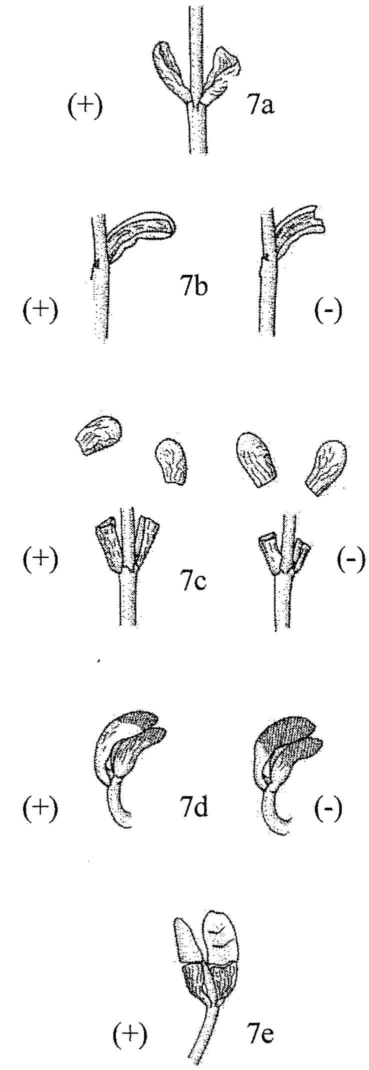


Fig. 7 Cotyledons, garden bean.



6a. Cotyledons missing but seedling vigorous.

6b. Cotyledons missing and seedling weak.

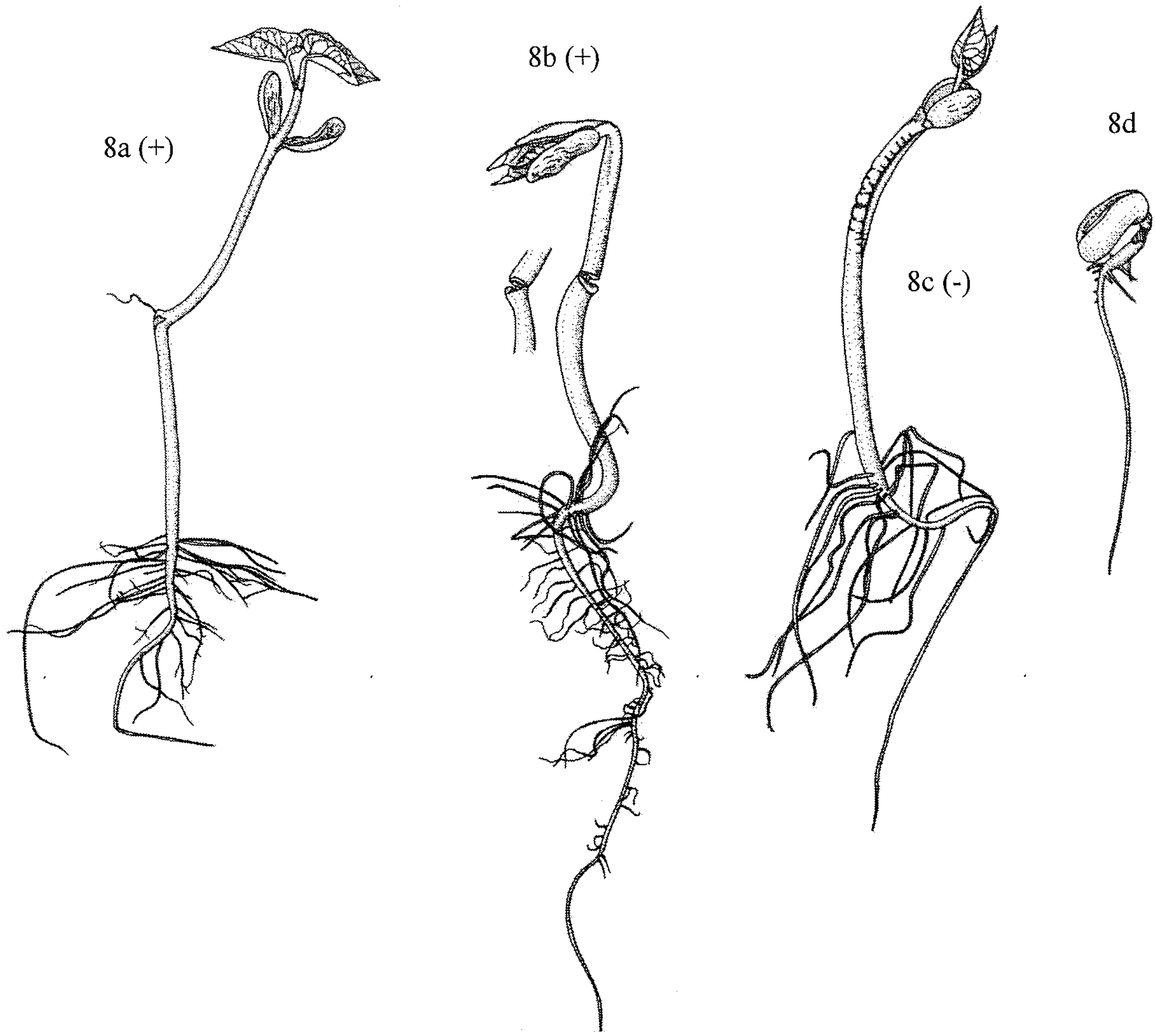
7a. Cotyledons shriveled, but intact.

7b. One cotyledon missing.

7c. Parts of both cotyledons missing.

7d. More than 50% of total cotyledon tissue decayed (this does not include firm, sound discolored tissue).

7e. Part of cotyledons non-functional but attached.



8a. Healed lesion ("knee").

8b. Hypocotyl break due to towel test.

8c. Deep lesion.

8d. Hypocotyl collar rot (retest using calcium nitrate, see AOSA Rules Vol. 1 Sec. 6.8 j).

Fig. 8 Hypocotyl defects.

FABACEAE, LEGUME FAMILY II - Soybean and lupine

Glycine max, soybean
Lupinus spp., lupine

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons that are large and fleshy; they expand, become photosynthetic and are usually persistent beyond the seedling stage.

Shoot system: The hypocotyl elongates and carries the cotyledons above the soil surface. The primary leaves usually increase in size and there may be epicotyl elongation within the test period.

Root system: A long primary root with secondary roots.

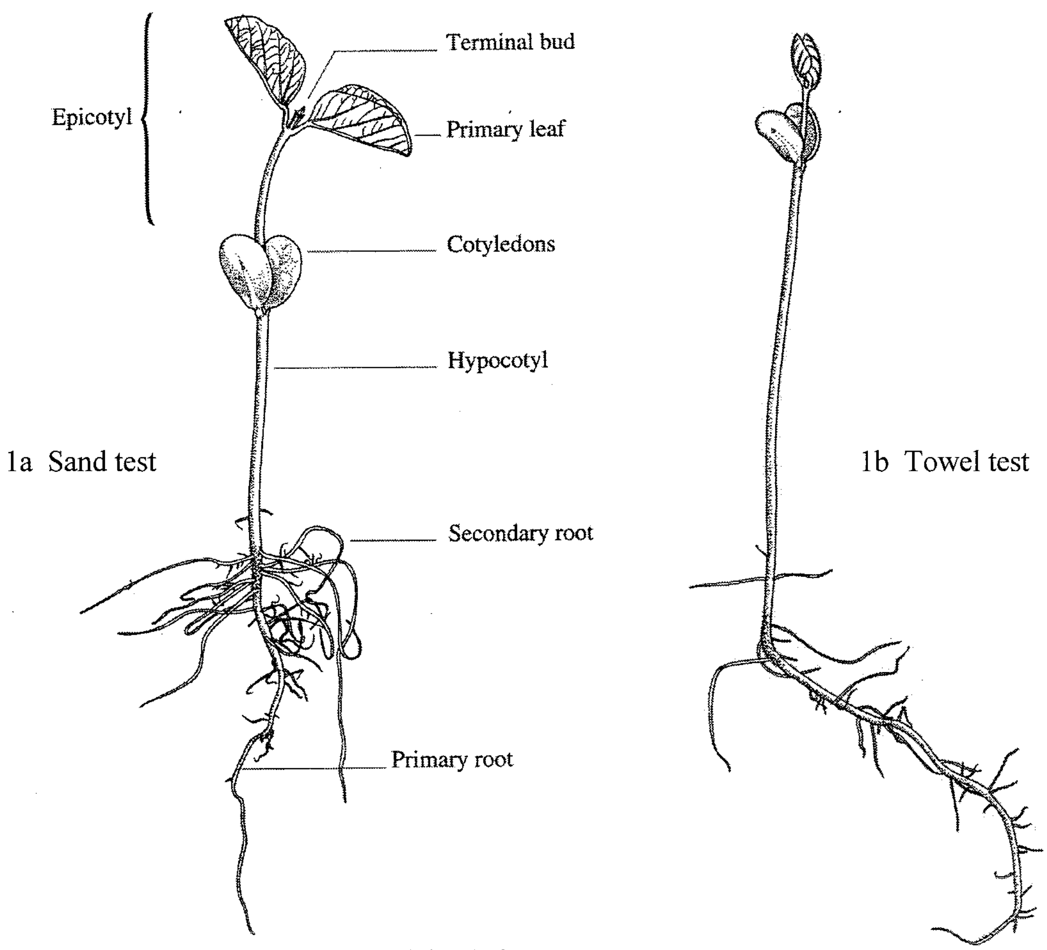


Fig. 1 Soybean.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:
- missing.
- less than one primary leaf.
- deep, open cracks.
- terminal bud damaged, missing or decayed (but see note 4).

Hypocotyl:
- deep open cracks extending into the conducting tissue (see note 8).
- malformed, such as markedly shortened, curled or thickened (see notes 1 and 5).

Root:
- none.
- weak, stubby or missing primary root with weak secondary or adventitious roots (see note 2).

Seedling:
- one or more essential structures impaired as a result of decay from primary infection (see note 3).
- albino.

NOTES

1. Towels rolled too tightly or tight rubber bands may constrict growing seedlings causing them to be malformed. Tight rolls, often in combination with a mid-test watering, may cause hypocotyl cracking or splitting. The tissue around such breaks often appears swollen.

2. Roots of seedlings on top of crepe cellulose paper (TC) under dry test conditions may not become established and hypocotyl elongation may appear to be abnormal. There may be curling of the root and hypocotyl. When a number of seedlings are observed with this condition, the sample should be retested.

3. Secondary infection is common in towel and blotter tests. Some pathogens (*Fusarium, Phomopsis, Rhizoctonia*) can spread through the substrate and infect seedlings some distance away from the primary source. Seedlings with secondary infection are to be classified as normal. A retest in sand or soil may be advisable.

4. If a few seedlings with a partial decay of the epicotyl are found, they may be classified as normal, provided the hypocotyl and root are normal. The epicotyl on such seedlings usually does not decay when grown in a fairly dry environment and is exposed to light. A retest, preferably in soil or sand, will aid in interpretation of such seedlings.

5. Hypocotyl development is slow until the roots start functioning and reach sufficient size; caution should be exercised to ensure slow seedlings are not classified as abnormal. This is especially evident for soybeans grown on top of crepe cellulose paper or in sand (S) if seeds aren't sufficiently

pressed in or covered (respectively), likely resulting in a very short, non-thickened hypocotyl with a long primary root. Similarly, epicotyls may remain undeveloped if the roots and hypocotyls are late in their development. A retest, preferably in soil or sand, will aid in interpretation of such seedlings.

6. A preliminary count is prescribed (see Table 6A of the AOSA Rules Vol. 1 for first count days), but caution should be exercised to avoid the possibility of misinterpreting small seedlings or causing damage. It is permissible to extend the test two days (see AOSA Rules Vol. 1 Sec. 6.9 d (4)) when slow growth or substrate effects have occurred. If, at the end of the germination period, there are swollen seeds or seeds that have just started to germinate, extend the test five days (see Sec. 4.9 d (6) of the AOSA Rules Vol. 1).

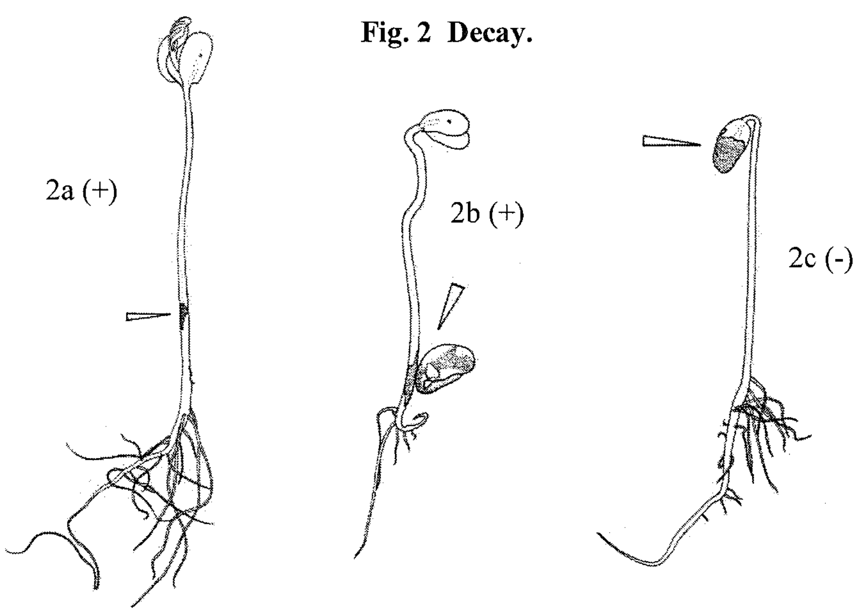
7. Dormancy seldom occurs but some seeds may be slower to start. Hard seeds may be present and are to be reported in addition to the percentage germination (see Sec. 6.2 d of the AOSA Rules Vol. 1).

8. Adventitious roots may occur at the site of any injury, particularly on the hypocotyl and near the base of the cotyledons. If the injury is healed over the seedling is to be classified as normal. See Section 3.5.9 for assessment of hypocotyl lesions.

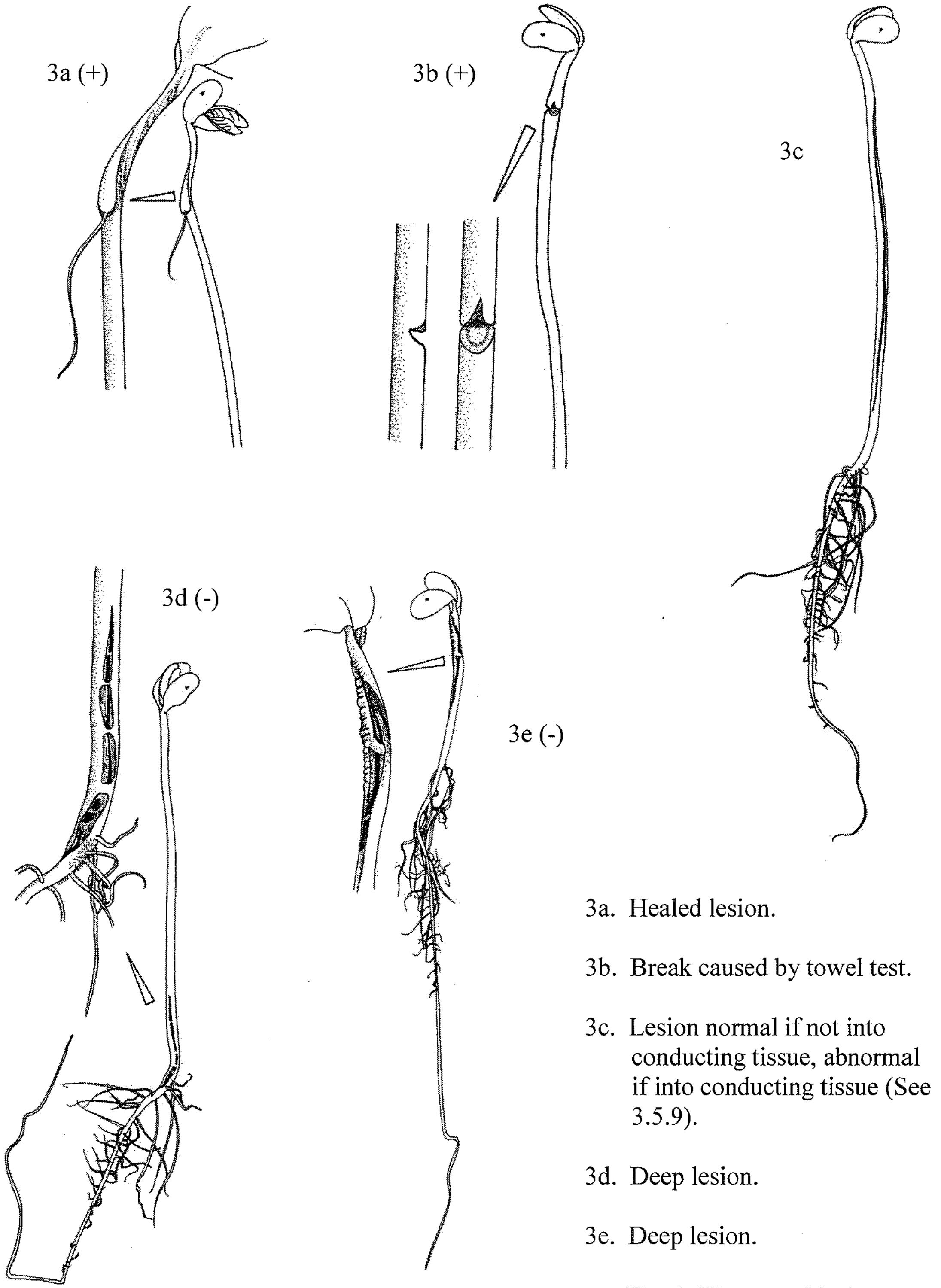
9. Large-seeded legumes are especially susceptible to threshing or combine damage. Seed that has been mechanically damaged may produce seedlings with damaged primary roots, hypocotyls or epicotyls, or broken or detached cotyledons. Bruised areas are usually necrotic or decayed. Damage at the point of attachment of the cotyledons may be difficult to evaluate if seedlings are removed too early in the test period.

10. It is desirable for roots and the hypocotyl to be in proportion or for the primary root to be longer than the hypocotyl. At a minimum, the hypocotyl should be at least the same size as one of the seedling's cotyledons.

Fig. 2 Decay.



2a. Decay on surface.
2b. Secondary infection from another seed or seed coat.
2c. More than 50% of total cotyledon tissue decayed (this does not include firm, sound, discolored tissue).



3a. Healed lesion.

3b. Break caused by towel test.

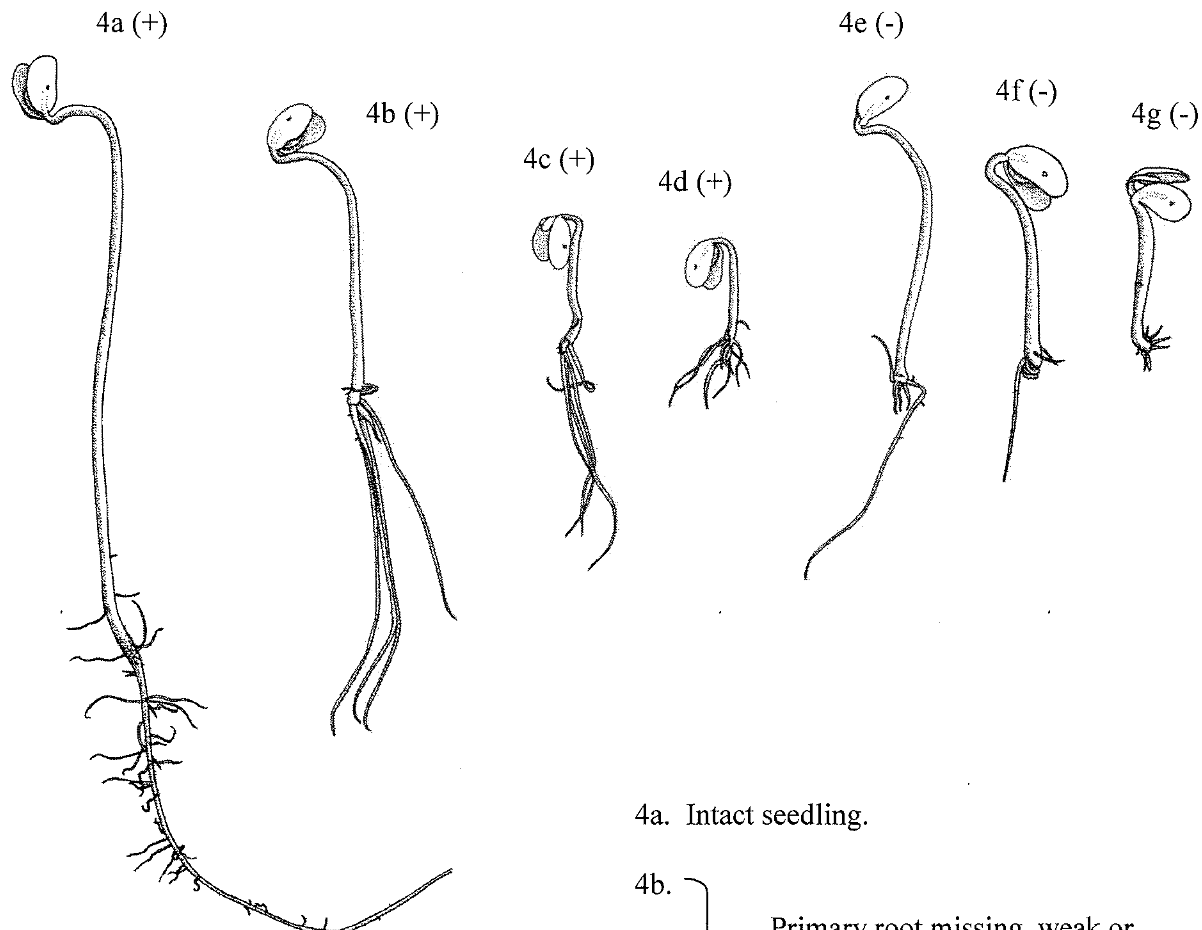
3c. Lesion normal if not into conducting tissue, abnormal if into conducting tissue (See 3.5.9).

3d. Deep lesion.

3e. Deep lesion.

Fig. 3 Hypocotyl lesions.

Fig. 4 Root defects.



4a. Intact seedling.

4b., 4c., 4d. } Primary root missing, weak or stubby, sufficient secondary roots.

4e., 4f., 4g. } Primary root missing, weak or stubby, insufficient secondary roots.

FABACEAE, LEGUME FAMILY III - Peanut

Arachis hypogaea, peanut

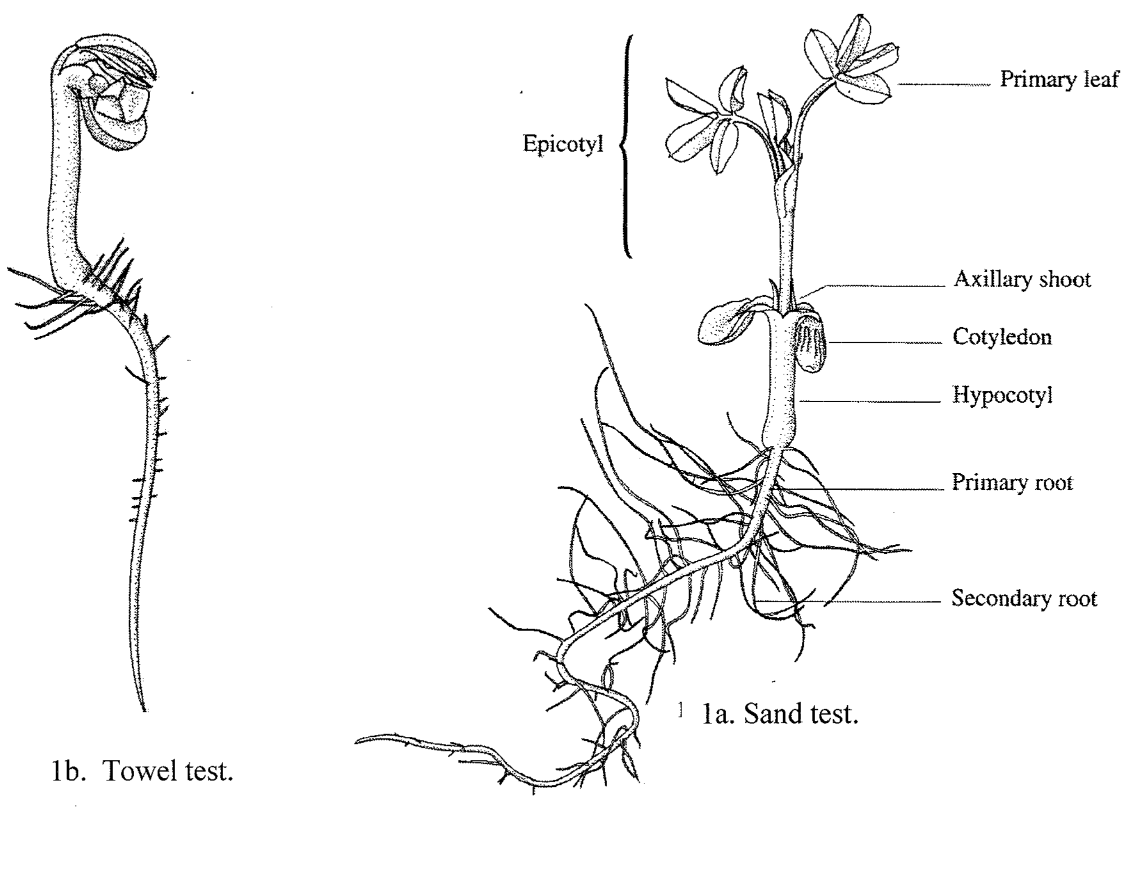
GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons that are large and fleshy.

Shoot system: The cotyledons are carried to the soil surface by the hypocotyl that is very thick, narrowing abruptly just above the root. Elongation of the hypocotyl stops when the epicotyl is exposed to light at the soil surface; often elongation stops before the cotyledons have broken through the surface. The primary leaves are compound and usually expand during the test period, although the epicotyl may be dormant.

Root system: A long primary root with secondary roots. Adventitious roots develop from the base of the hypocotyl if the primary root is damaged.



1a. Sand test.

1b. Towel test.

Fig. 1 Peanut.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:
- missing.
- less than one primary leaf.
- deep, open cracks.
- terminal bud damaged, missing or decayed.

Hypocotyl:
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened or curled (see notes 1 and 2).

Root:
- none.
- weak, stubby or missing primary root with weak secondary or adventitious roots (see note 3).

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. Hypocotyls remain somewhat thickened and may appear to be stunted. Light, depth of planting and substrate moisture all contribute to the length of the hypocotyl.

2. Hypocotyl stunting and curling may be caused by constriction and/or seedling orientation on or in the substrate.

3. Seedlings planted in a soil test with the radicle too close to the surface may send roots above the soil and appear to exhibit negative geotropism and a distorted hypocotyl (U-shaped).

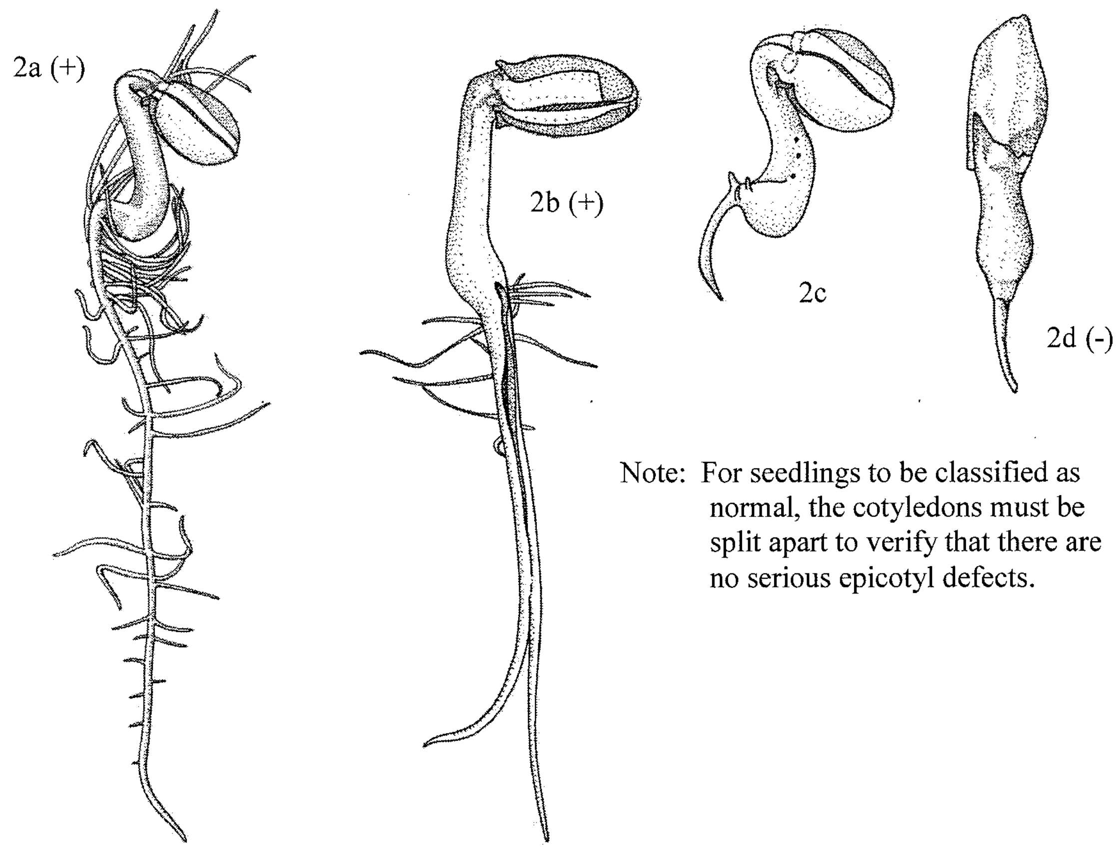
4. If necessary for the seedling to reorient itself for emergence, it may form a neck that includes the base of the cotyledons. In this case both cotyledons will be bent to one side and carried well above the soil surface. If oriented with the radicle pointing downward, the seedling may not form a neck but will push the cotyledons directly up to the surface.

5. Freshly harvested peanuts may exhibit varying degrees of dormancy. It is often necessary to resort to artificial means of breaking dormancy in order to achieve satisfactory germination (see Sec. 6.9 h and Sec. 6.9 i of the AOSA Rules Vol. 1).

REFERENCES

Gavrielith-Gelmond, H. 1962. A review of problems associated with testing of peanut seed (*Arachis hypogaea*). Proc. Int. Seed Test. Ass., 27:357-372.

Fig. 2 Root defects.



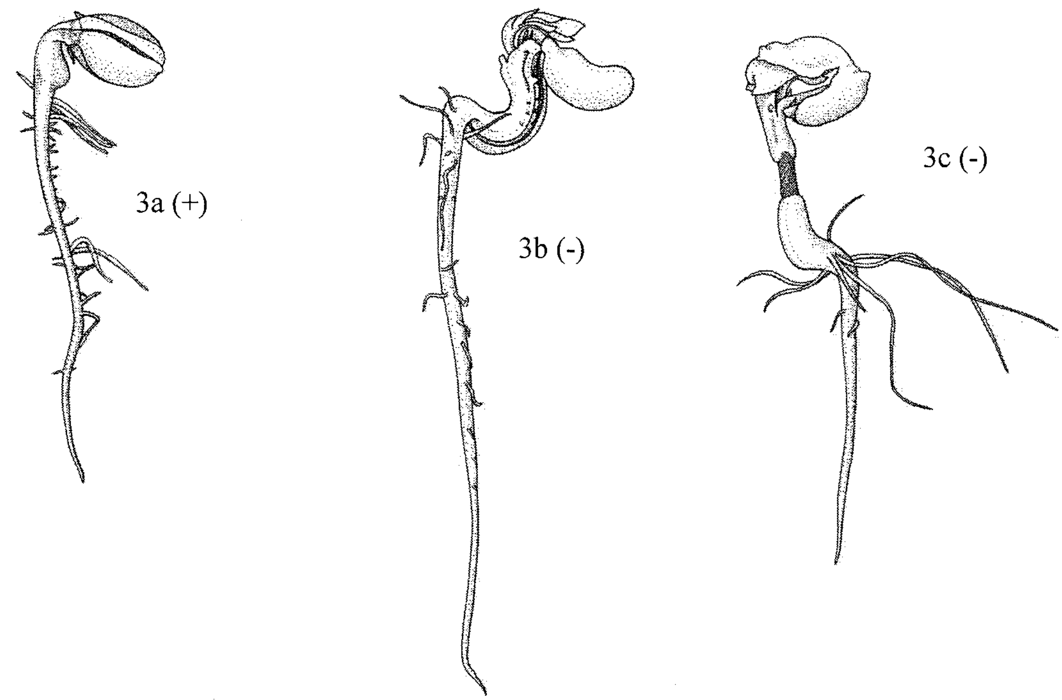
Note: For seedlings to be classified as normal, the cotyledons must be split apart to verify that there are no serious epicotyl defects.

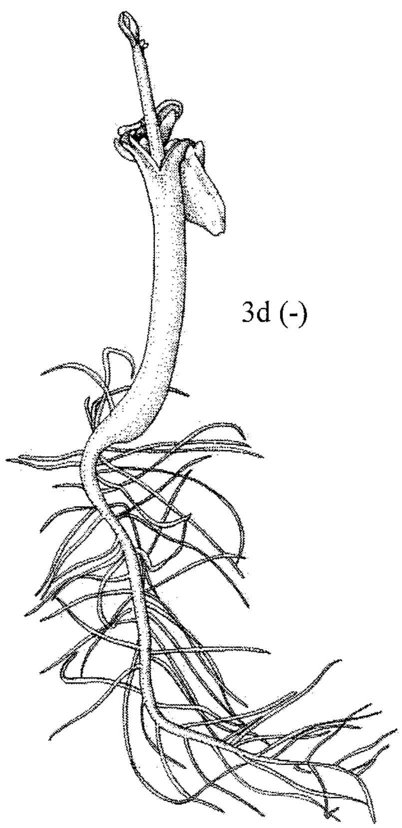
2a. Intact seedling.

2b. Split root, split not extending into hypocotyl.

2c. Seedling too small to evaluate; extend test (see 3.5.1.b).

2d. Stubby primary root, no secondary roots developing.





3a. Hypocotyl short but seedling developing normally.

3b. Deep hypocotyl lesion.

3c. Collapse of hypocotyl tissue (nutrient deficiency).

3d. Missing primary leaves.

Fig. 3 Peanut.

FABACEAE, LEGUME FAMILY IV - Large-seeded hypogeal

Cicer arietinum, chickpea
Lathyrus hirsutus, rough-pea
Lathyrus sylvestris, flat-pea
Lens culinaris subsp. *culinaris*, lentil
Mucuna pruriens var. *utilis*, velvetbean
Phaseolus coccineus, scarlet runner bean
Pisum sativum, pea (field or garden)
Vicia faba, horsebean or broadbean
Vicia spp., vetch
Vigna angularis, adzuki bean

GENERAL DESCRIPTION

Seedling type: Hypogeal dicot.

Food reserves: Cotyledons that are large and fleshy, and remain enclosed within the seed coat beneath the soil surface. They are usually not photosynthetic.

Shoot system: The epicotyl elongates and carries the terminal bud and primary leaves above the soil surface. The stem bears one or more scale leaves and, prior to emergence, is arched near the apex, causing the terminal bud to be pulled through the soil; after emergence, the stem straightens. For practical purposes the hypocotyl is not discernible and is not an evaluation factor. There are buds in the axils of each cotyledon and scale leaf but these usually remain dormant unless the terminal bud is seriously damaged. In this case, one or more axillary buds will start to develop, forming a secondary epicotyl.

Root system: A long primary root with secondary roots.

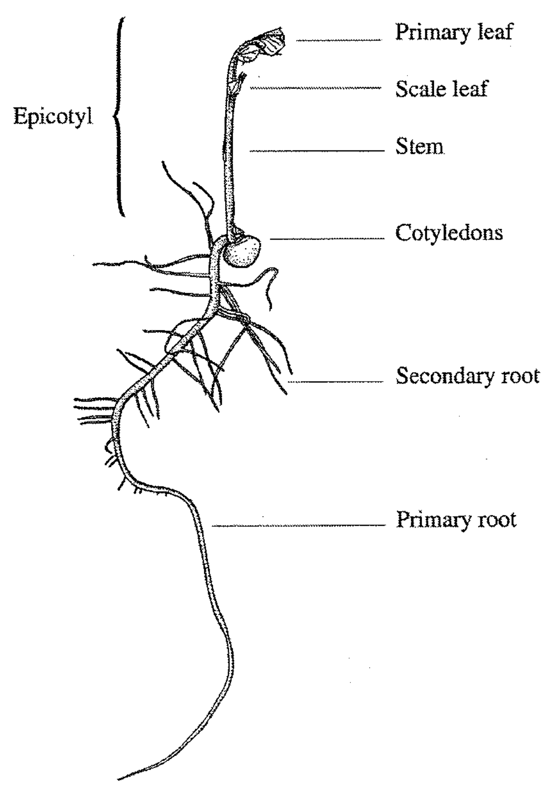


Fig. 1 Pea.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached (see notes 6 and 7).
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:
- missing.
- less than one primary leaf.
- malformed stem such as markedly shortened, curled, or thickened.
- severely damaged (e.g. terminal bud missing or damaged) with only a weak secondary epicotyl developing from the axil of a cotyledon or scale leaf.
- two weak epicotyls.
- deep, open cracks extending into the conducting tissue.

Root:
- none.
- weak, stubby or missing primary root with weak secondary roots.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. There is a greater likelihood of hard seed expression when the substrate does not provide adequate moisture to the seeds throughout the test period.

2. Insufficient moisture will result in apparently disproportionate elongation of the primary root and slow development of the epicotyl.

3. The percentage of hard seeds is to be reported in addition to the percentage germination (see Sec. 6.2 d of the AOSA Rules Vol. 1).

4. If at the end of the germination period there are swollen seeds present, or seeds that have just started to germinate, remove everything but these seeds and continue the test. After additional days prescribed in 6.9 m (6), add any normal seedlings to the previous count (see Sec. 6.9 d (6) and Sec. 6.9 m (6) of the AOSA Rules Vol. 1).

5. Manganese deficiency at the time of seed development may cause a condition known as "marsh spot", characterized by a discolored brown indentation in the center of the inner surfaces of the cotyledons. Seedlings with this condition are considered normal, provided they are otherwise normal. If the condition causes difficulty in evaluation, then the sample should be retested in soil.

6. Weevil infestation may prevent the development of a normal seedling. Sometimes the cotyledons have been devoured to the extent that no food supply is left for the developing seedling. Such injury can be easily detected by examining the cotyledons.

7. Large-seeded legumes are especially susceptible to threshing or combine damage. Seed that has been mechanically damaged may produce seedlings with damaged primary roots, hypocotyls or epicotyls, or broken or detached cotyledons. Bruised areas are usually necrotic or decayed. Damage at the point of attachment of the cotyledons may be difficult to evaluate if seedlings are removed too early in the test period.

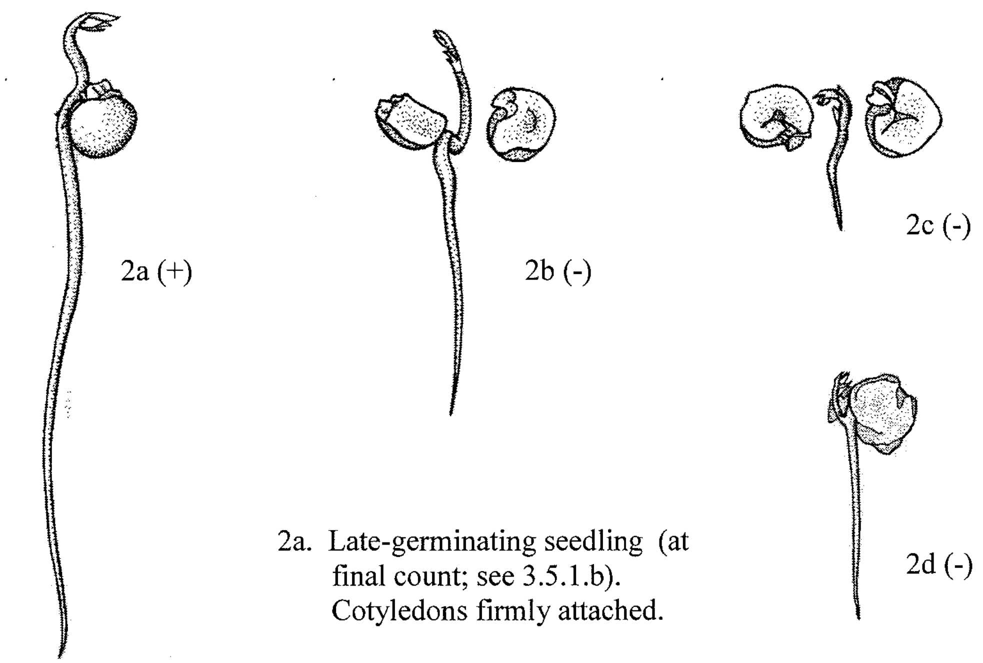
REFERENCES

Bradnock, W., C. L. Plommer, J. Matheson, M. Fiedorowicz. 1972. Preventing blackening of broad bean (*Vicia faba* L.) seedlings with calcium nitrate. Proc. Assoc. Off. Seed Anal., 62:125-129.

Cuddy, T. F. 1959. Marsh spot of peas. Proc. Assoc. Off. Seed Anal., 49:156-158.

Rush, C. M. 1987. Incidence of hollow heart of *Pisum sativum* in the Pacific Northwest. J. Seed Technol., 2:121-130.

Fig. 2 Cotyledon defects.

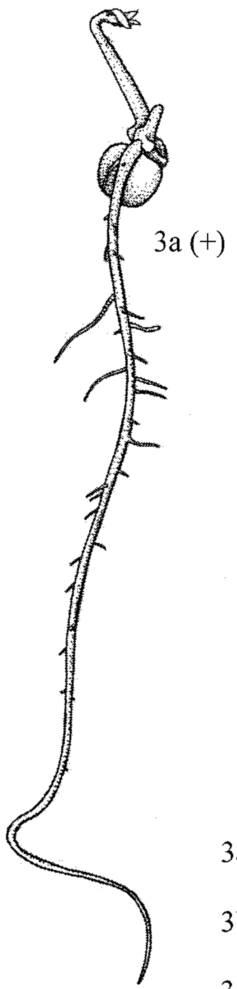


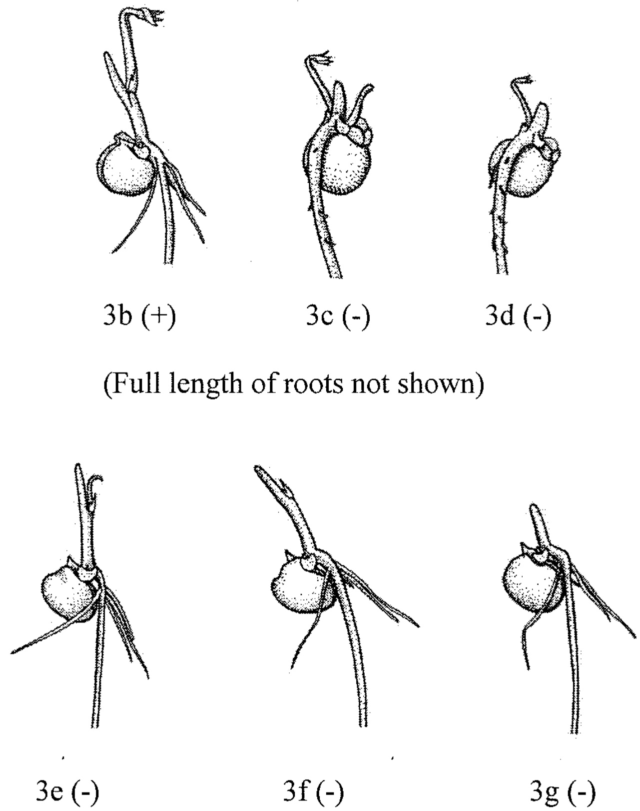
2a. Late-germinating seedling (at final count; see 3.5.1.b). Cotyledons firmly attached.

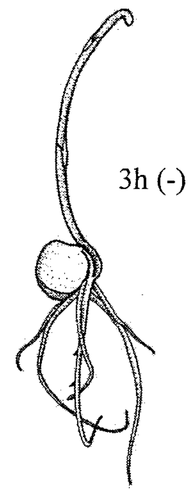
2b. One cotyledon attached and damaged.

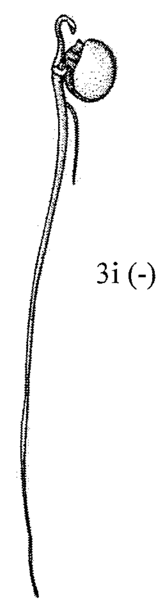
2c. Both cotyledons detached.

2d. Cotyledons attached, but more than half decayed.









3a. Strong secondary epicotyl from axil of cotyledon.

3b. Strong secondary epicotyl from axil of scale leaf.

3c. Two weak secondary epicotyls from axils of cotyledons. Terminal bud and primary leaf missing from primary epicotyl.

3d. One weak secondary epicotyl from axil of cotyledon. Terminal bud and primary leaf missing from primary epicotyl.

3e. One weak secondary epicotyl from axil of scale leaf.

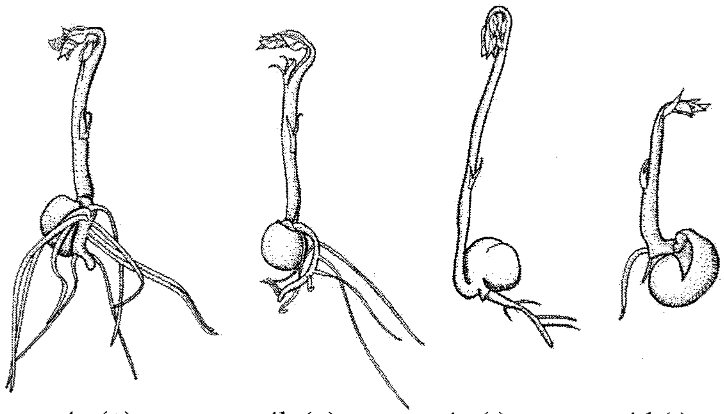
3f. Terminal bud and primary leaf missing.

3g. Terminal bud and primary leaf missing.

3h. Terminal bud and primary leaf missing.

3i. Weak epicotyl. One or both cotyledons detached.

Fig. 3 Epicotyl defects.



4a (+) 4b (+) 4c (-) 4d (-)

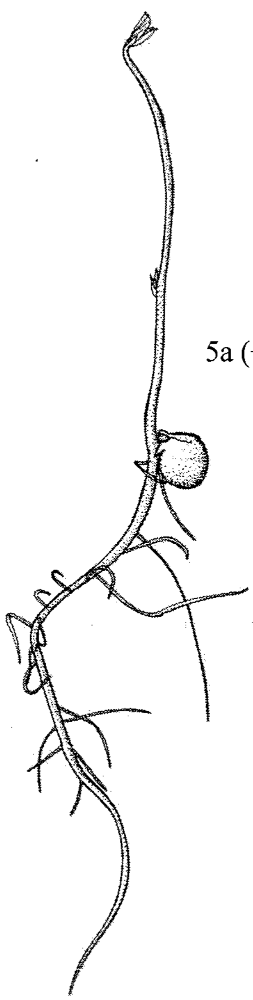
4a. Stubby primary root, sufficient secondary roots.

4b. Stubby primary root, sufficient secondary roots.

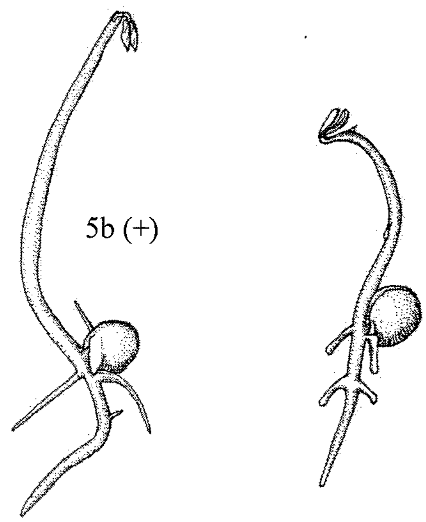
4c. Stubby primary root, insufficient secondary roots.

4d. Insufficient roots.

Fig. 4 Root defects – Pea.



5a (+)



5b (+) 5c (-)

5a. Intact lentil seedling.

5b. Stubby primary root with secondary roots developing.

3c. Stubby primary root with stubby secondary roots.

Fig. 5 Root defects – Lentil.

FABACEAE, LEGUME FAMILY V - Small-seeded

Alysicarpus vaginalis, alyceclover
Astragalus cicer, cicer milkvetch
Crotalaria spp., crotalaria
Cyamopsis tetragonoloba, guar
Desmodium tortuosum, beggarweed
Hedysarum boreale, northern sweetvetch
Indigofera hirsuta, hairy indigo
Kummerowia spp., lespedeza
Lespedeza spp., lespedeza
Lotus spp., trefoil
Medicago arabica, spotted burclover
Medicago lupulina, black medic
Medicago orbicularis, buttonclover
Medicago polymorpha, California burclover
Medicago sativa subsp. *sativa*, alfalfa
Melilotus indicus, sourclover
Melilotus spp., sweetclover
Onobrychis viciifolia, sainfoin
Pueraria montana var. *lobata*, kudzu
Securigera varia, crownvetch
Sesbania exaltata, sesbania
Trifolium spp., clover

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons that are small and fleshy; they expand, and become photosynthetic.

Shoot system: The hypocotyl elongates and carries the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A long tapering primary root, usually with roots hairs. Most of the included species do not normally develop secondary roots within the test period.

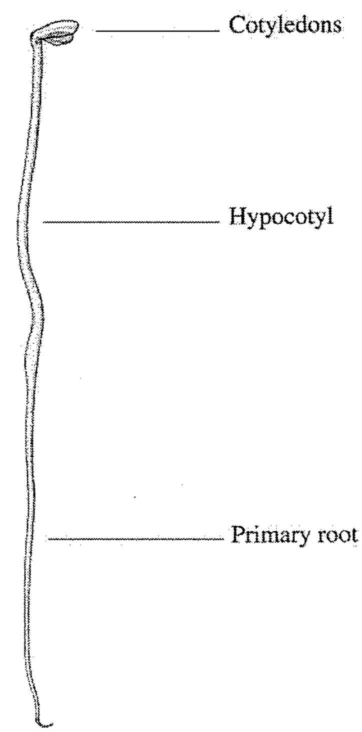


Fig. 1 Alfalfa.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached (see note 2).
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:
- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl:
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.
- watery.

Root:
- none.
- primary root stubby (for sweetclover and crownvetch, or for roots bound by the seed coat see note 1).
- split extending into the hypocotyl.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. Stubby roots when germinated on artificial media:

    a) Sweetclover - the roots of sweetclover may be stubby due to the presence of coumarin in the seed. Since this condition usually does not occur in soil, such seedlings are to be classified as normal.

    b) Bound by coat - roots may appear stubby as a result of being bound by the seed coat. Such seedlings are to be classified as normal.

    c) Crownvetch - produces phytotoxic effects similar to sweetclover.

2. Breaks at the point of attachment of the cotyledons to the hypocotyl are common in seeds that have been mechanically damaged. It is important that seedlings not be removed during preliminary counts unless development is sufficient to allow the condition of the cotyledons to be determined. If the point of attachment of the cotyledons cannot be seen at the end of the test, the seed coat should be peeled back to determine whether a break has occurred.

3. Mechanical breakage of the seed may result in only vestiges of seedlings with swollen cotyledons and broken, slightly enlarged hypocotyls or radicles. Insect damage may also cause lack of seedling growth.

4. Seedlings of sainfoin that have been "strangled" by growing through the netting of the pod but that are otherwise normal are to be classified as normal.

5. The percentage of hard seeds must be determined at the end of the test period for all genera in this group. Swollen seeds that fail to germinate by the end of the test should be allowed an additional five days as provided in the AOSA Rules Vol. 1 (Sec. 6.9 d (6)). For swollen seeds of alyceclover, see AOSA Rules Vol. 1 Sec. 6.8 a and for crownvetch, see Sec. 6.8 o. Swollen seeds are an indication of dormancy and can be induced by incorrect temperatures.

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Anderson, A. M. 1954. A study of normal and abnormal seedlings of some small seeded legumes. Proc. Assoc. Off. Seed Anal., 44:188-201.

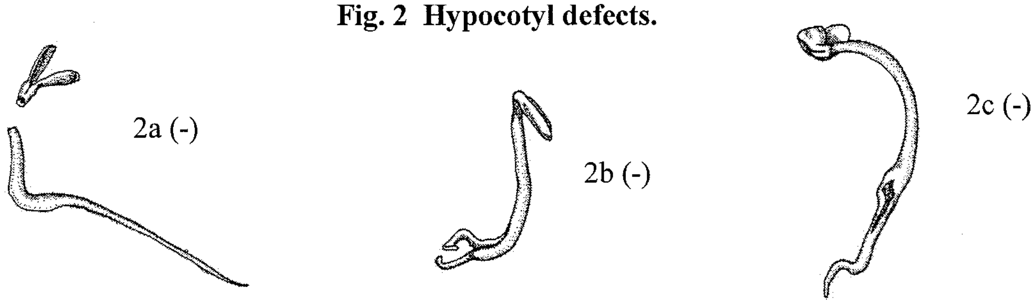
Anderson, A. M. 1957. Evaluation of normal and questionable seedlings of species of *Melilotus*, *Lotus*, *Trifolium* and *Medicago* by greenhouse tests. Proc. Int. Seed Test. Ass., 22:237-258.

Forsyth, D. B. 1963. Stubby roots caused by coumarin in sweetclover seed germination tests. Proc. Assoc. Off. Seed Anal., 53:119-123.

McKee, G. W., A. R. Langill, W. P. Ditmer and P. K. Joo. 1971. Germination and seedling growth of 48 plant species as affected by a leachate from seeds of *Coronilla varia* L. Crop Sci., 11:614-617.

Porter, C. R. and M. Buck. 1955. Germination of alfalfa as affected by contact with abnormal sweetclover on germination trays. Proc. Assoc. Off. Seed Anal., 45:72-74.

Fig. 2 Hypocotyl defects.



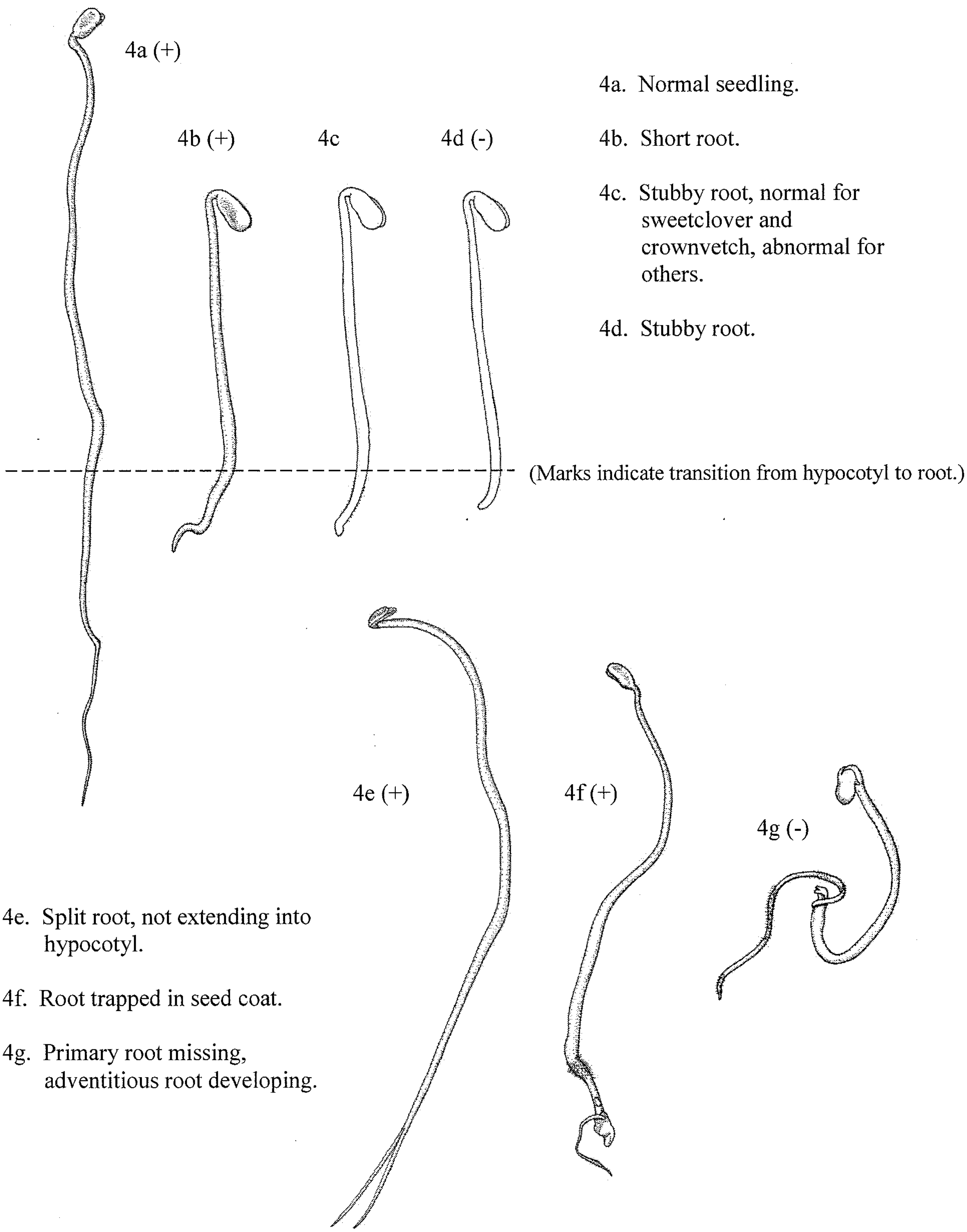
2a. Broken hypocotyl.
2b. Split root and hypocotyl.
2c. Deep lesion of hypocotyl.

Fig. 3 Small seedlings.

3a (+) 3b 3c (-)

3a. Late-germinating seedling (at final count; see 3.5.1.b).
3b. Seedling too small to evaluate; extend test (see 3.5.1.b).
3c. Swollen hypocotyl, stubby root.

Fig. 4 Root defects.



4a. Normal seedling.

4b. Short root.

4c. Stubby root, normal for sweetclover and crownvetch, abnormal for others.

4d. Stubby root.

4e. Split root, not extending into hypocotyl.

4f. Root trapped in seed coat.

4g. Primary root missing, adventitious root developing.

GERANIACEAE, GERANIUM FAMILY

Erodium cicutarium, alfilaria
Pelargonium spp., geranium

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons that expand and become thin, leaf-like and photosynthetic.

Shoot system: The hypocotyl elongates and carries the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A primary root; secondary roots or root hairs may develop within the test period.

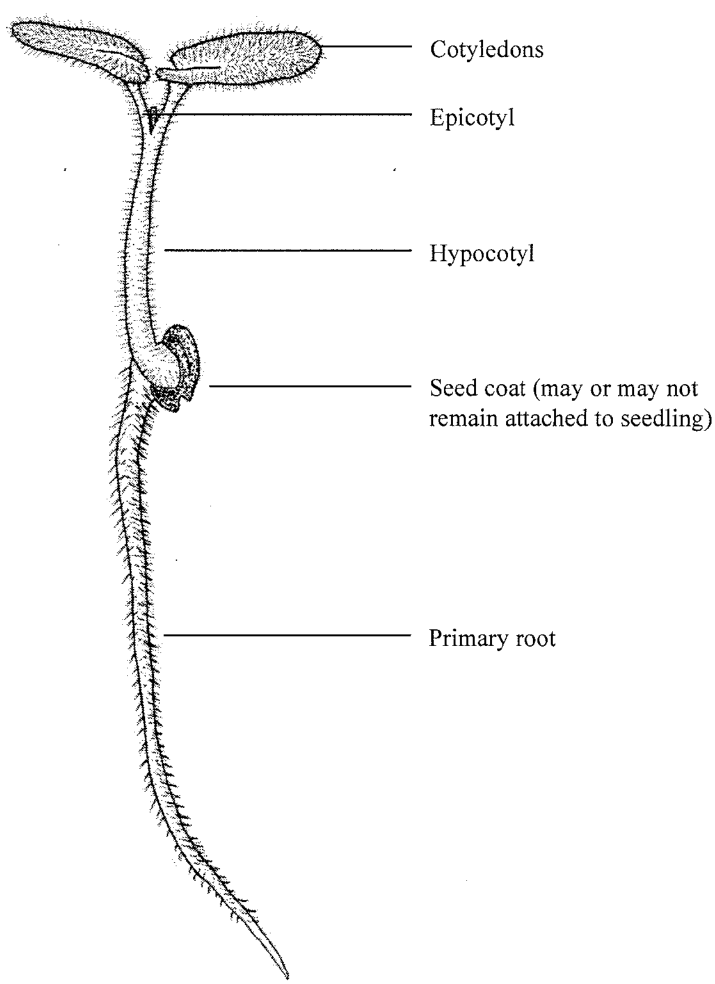


Fig. 1 Geranium.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:

- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay (see note 1).

Epicotyl:

- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl:

- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.
- watery (see note 2).

Root:

- none.
- weak, stubby or missing primary root; secondary roots will not compensate for a defective primary root (see notes 4 and 5).

Seedling:

- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. Seedlings with yellow (chlorotic) areas on the cotyledons are to be classified as abnormal if less than 50% of the original tissue is functioning normally.

2. Seedlings may be susceptible to damping off or disease conditions, resulting in brown watery tissue on any part of the seedling. Watery seedlings are considered abnormal if not caused by test conditions. Seedlings with secondary infection are to be classified as normal. If a high percentage of infected seeds are present, retest with lower moisture content of the substrate.

3. In *Pelargonium* spp., a natural purplish pigmentation is sometimes present on the hypocotyl; this is considered normal.

4. Secondary or adventitious roots may develop within the test period; this would be considered normal as long as the primary root is also present.

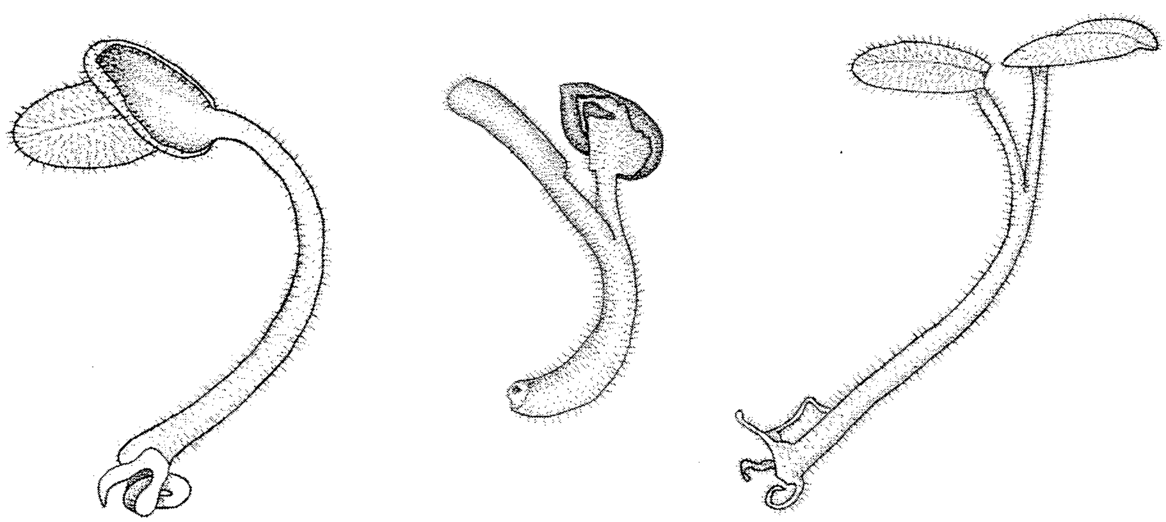
5. A seedling with the root bound within a tough seed coat is to be considered normal as long as the primary root is found to be present when the seed coat is removed for evaluation.

6. Species in the Geraniaceae typically have large percentages of dormant and hard seeds. For hard seeds, swollen seeds, and seeds which have just started to germinate, refer to Sec. 6.9 d (6) and Sec. 6.9 m (6) of the AOSA Rules Vol. 1.

7. It is often necessary to resort to artificial means of breaking dormancy. For *Pelargonium* spp., if at the end of the 5 additional days of testing (see Sec. 6.9 m (6) of the AOSA Rules Vol. 1) swollen seeds remain ungerminated, such seeds should be clipped on the cotyledon end (see Figure 4) and allowed to remain in test for an additional 5 days. Clipped seeds that subsequently germinate and produce normal seedlings shall be reported as dormant.

8. Samples for testing *Pelargonium* spp. may come in three types of seed units: seed in hull (mericarp) with or without coiled beak/stiff hairs; seed dehulled but not scarified (abrasion of seed coat); or seed dehulled and scarified. Scarified seed often germinates readily; Table 6A of the AOSA Rules Vol. 1 lists an alternate method (shorter test period) for clipped and scarified seeds of *Pelargonium* spp. The scarification process can sometimes create additional root problems.

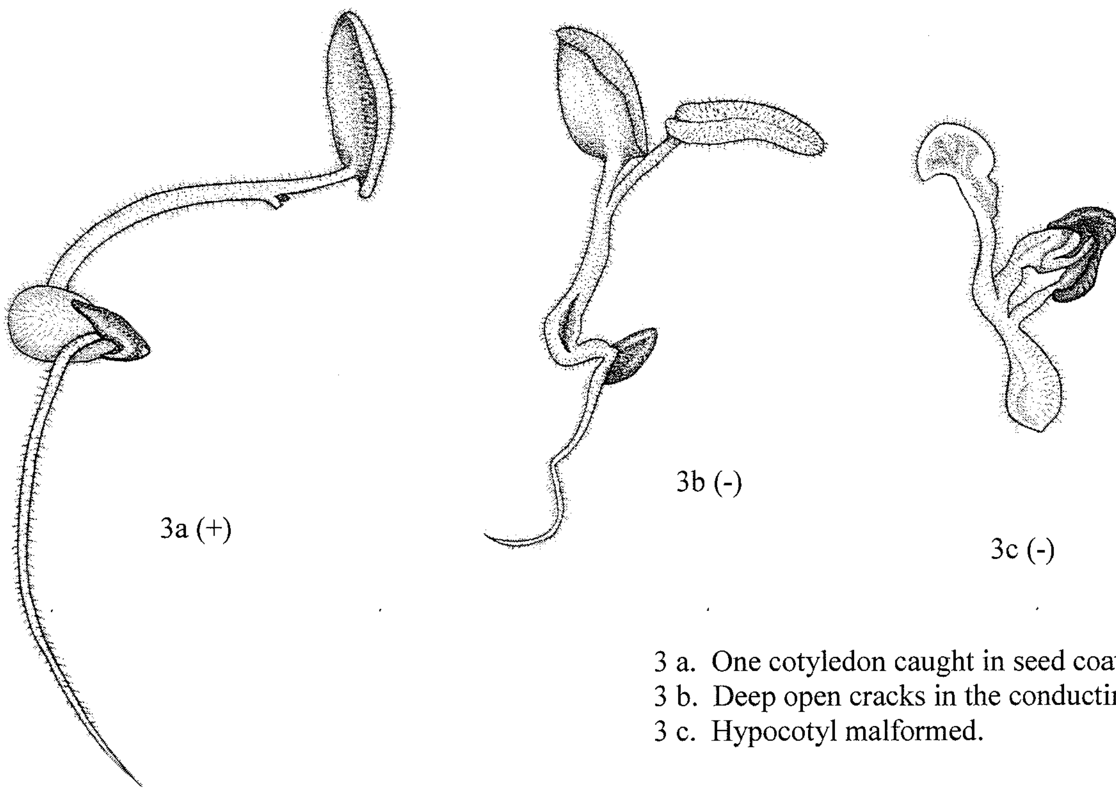
Fig. 2 Root defects.



2a (+) 2b (-) 2c (-)

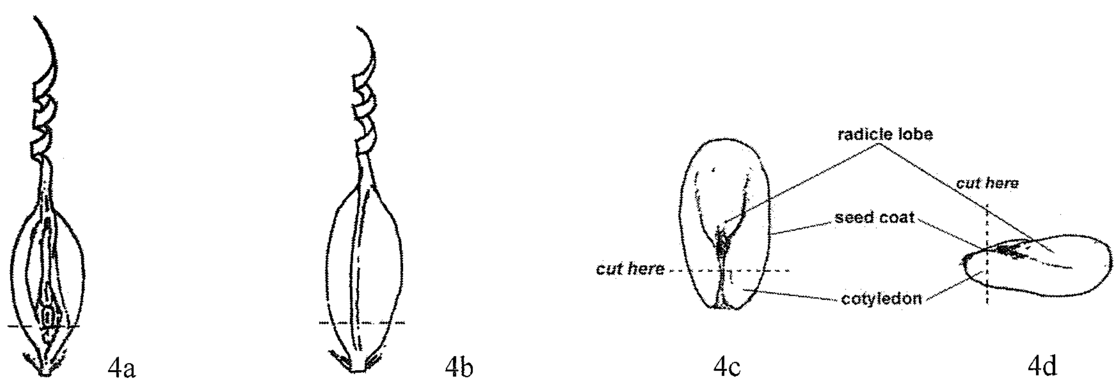
2 a. Primary root present, originally bound in seed coat; seed coat removed for evaluation (see note 5).
2 b. Root missing.
2 c. Primary root stubby; weak secondary root.

Fig. 3 Cotyledon and hypocotyl defects.



3 a. One cotyledon caught in seed coat.
3 b. Deep open cracks in the conducting tissue.
3 c. Hypocotyl malformed.

Fig. 4 Seed units - clipping diagrams.



4 a. Seed in hull; front view.
4 b. Seed in hull; back view.
4 c. Dehulled seed; front view.
4 d. Dehulled seed; profile view.

LILIACEAE, LILY FAMILY I - Asparagus

[Asparagaceae is the preferred family name according to GRIN]

Asparagus officinalis, asparagus

GENERAL DESCRIPTION

Seedling type: Hypogeal monocot.

Food reserves: Endosperm that is hard, semi-transparent and non-starchy; minor reserves in the cotyledon. The endosperm surrounds the entire embryo.

Cotyledon: A single cylindrical cotyledon; following germination all but the basal end remains embedded in the endosperm to absorb nutrients.

Shoot system: The epicotyl elongates and carries the terminal bud and primary leaves above the soil surface. The epicotyl may bear several small scale leaves. A short hypocotyl is barely distinguishable joining the root to the basal end of the cotyledon, which emerges from the seed.

Root system: A long slender primary root.

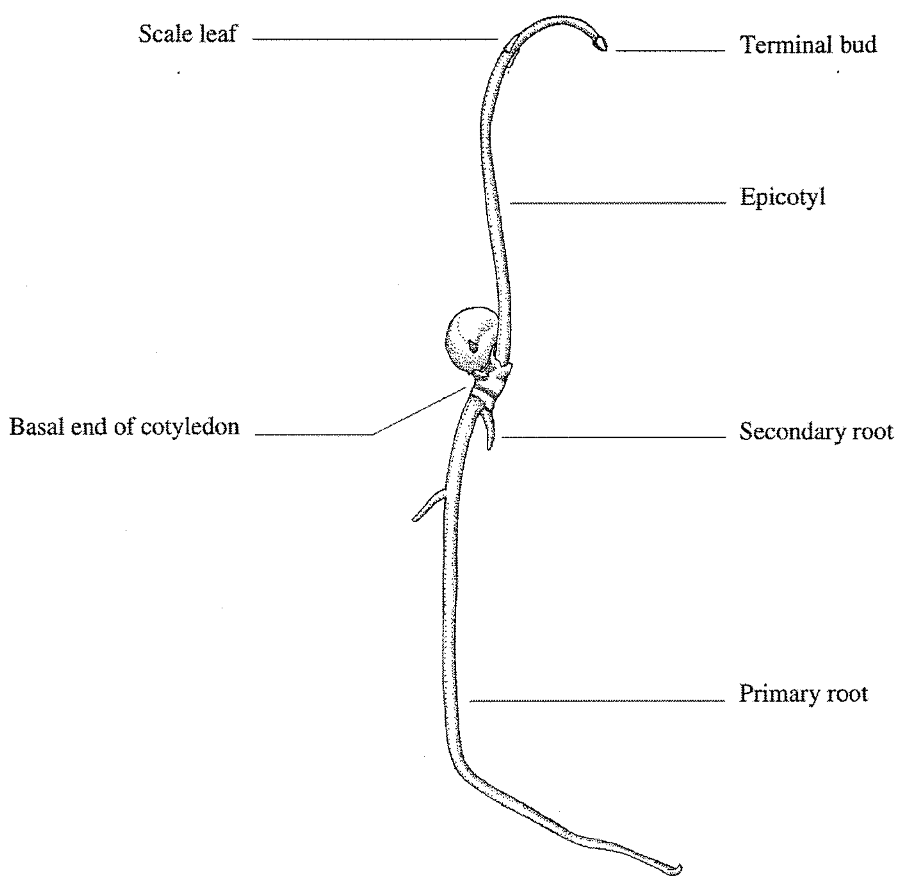


Fig. 1 Asparagus.

ABNORMAL SEEDLING DESCRIPTION

Cotyledon:
- detached from seedling.

Epicotyl:
- missing.
- terminal bud missing or damaged.
- deep, open cracks.
- malformed, such as markedly shortened, curled, or thickened.
- spindly.
- watery.
- (see also note 1).

Hypocotyl:
- not evaluated.

Root:
- no primary root.
- stubby primary root, with weak secondary roots (but see note 3 for ornamental asparagus).

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. Several epicotyls may arise simultaneously and may be considered normal if at least one appears to be vigorous and has a terminal growing point.

2. Some seeds do not contain an embryo. Firm seeds may be cut and tested for viability (see Sec. 6.9 m of the AOSA Rules Vol. 1) to determine the presence of a viable embryo. Viable ungerminated seeds may be reported as dormant.

3. Ornamental asparagus (*Asparagus setaceus* and *A. densiflorus*) has a thickened primary root, in contrast to the long, slender root of the garden asparagus (*A. officinalis*).

2a (-)

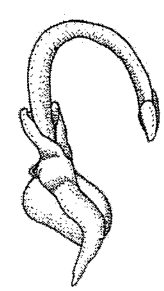


Fig. 2 Root defect.

2a. Stubby primary root.

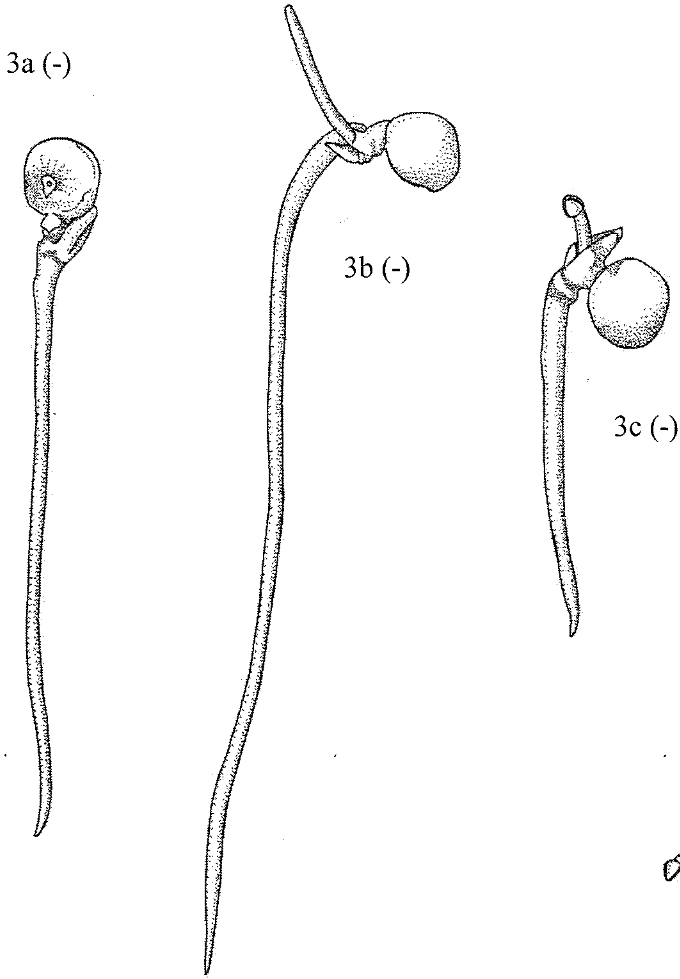
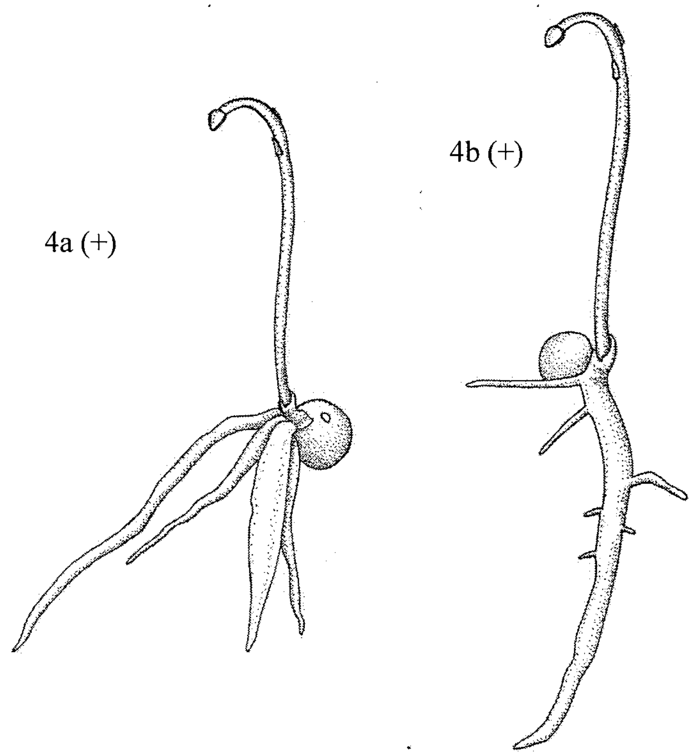


Fig. 3 Epicotyl defects.

3a. Epicotyl missing.

3b. Terminal bud missing.

3c. Epicotyl markedly shortened.



4a. *Asparagus densiflorus*.

4b. *Asparagus setaceus*.

Fig. 4 Ornamental asparagus with thickened primary root.

LILIACEAE, LILY FAMILY II - Onion, leek and chives

[Amaryllidaceae is the preferred family name according to GRIN]

Allium cepa, onion
Allium porrum, leek
Allium schoenoprasum, chives

GENERAL DESCRIPTION

Seedling type: Epigeal monocot.

Food reserves: Endosperm that is hard, semi-transparent and non-starchy; minor reserves in the cotyledon.

Cotyledon: A single cylindrical cotyledon; following germination the tip remains embedded in the endosperm to absorb nutrients.

Shoot system: The cotyledon emerges with the seed coat and endosperm attached to the tip. A sharp bend known as the "knee" forms; continued elongation of the cotyledon on each side of this knee pushes it above the soil surface. The cotyledon tip is pulled from the soil and straightens except for a slight kink that remains at the site of the knee. The first foliage leaf emerges through a slit near the base of the cotyledon, but this does not usually occur during the test period. The hypocotyl is a very short transitional zone between the primary root and the cotyledon.

Root system: A long slender primary root with adventitious roots developing from the hypocotyl. The primary root does not develop secondary roots.

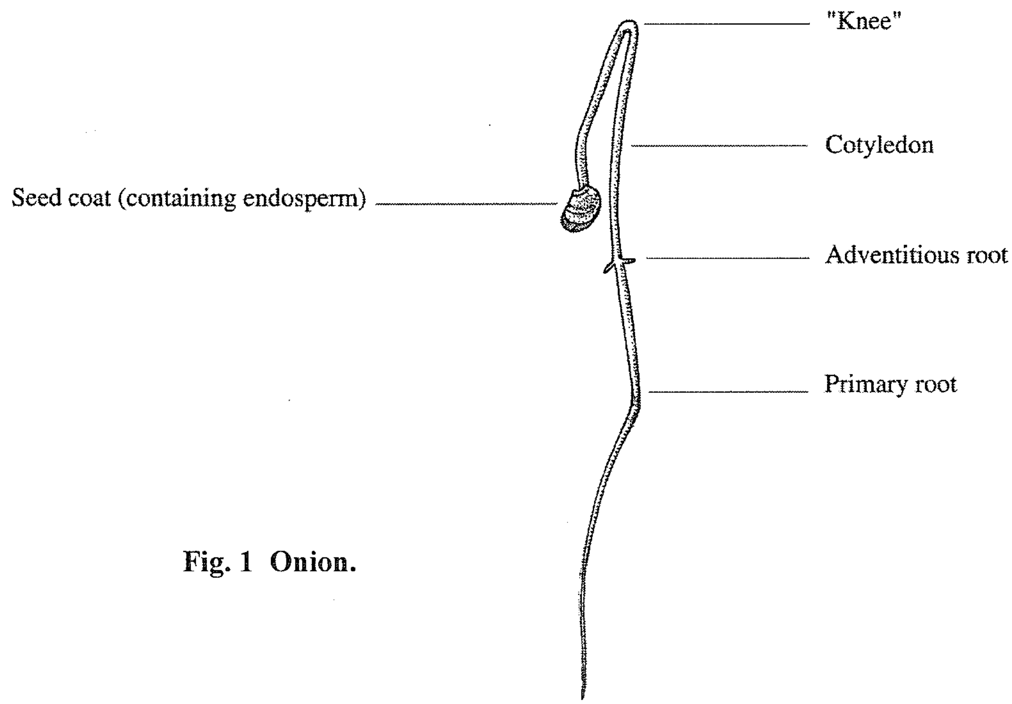


Fig. 1 Onion.

ABNORMAL SEEDLING DESCRIPTION

Cotyledon:
- short and thick.
- without a definite bend or "knee".
- spindly or watery.

Epicotyl:
- not observed during the test period.

Hypocotyl:
- not evaluated.

Root:
- no primary root.
- short, weak or stubby primary root.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. Excess moisture may cause a delay in germination causing some seed lots to appear dormant.

2. Blotter or towel tests of onion are commonly overcome with fungus. To reduce this problem on a retest, seeds should be spaced farther apart.

3. Multiple seed units (adhering pairs of seeds) are sometimes present in *Allium* spp. A multiple seed unit producing at least one normal seedling is classified as normal; only one normal seedling per pair is to be counted. Care should be taken at the beginning of the germination test to identify the multiple seed units because the adhering pairs of seeds may separate during the germination process.

2a. Slight "knee" visible.

2b. No "knee" visible.

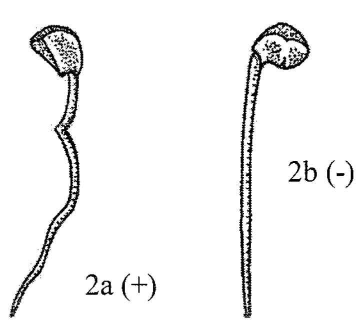


Fig. 2 Cotyledon "knee".

3a. Slightly stubby root.

3b. Stubby root, with adventitious roots started.

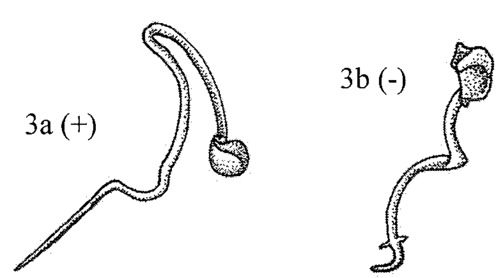


Fig. 3 Root defects.

LINACEAE, FLAX FAMILY

Linum usitatissimum, flax

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons that expand and become photosynthetic. They persist for about one month following germination.

Shoot system: The hypocotyl elongates carrying the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A primary root, with secondary roots usually developing within the test period.

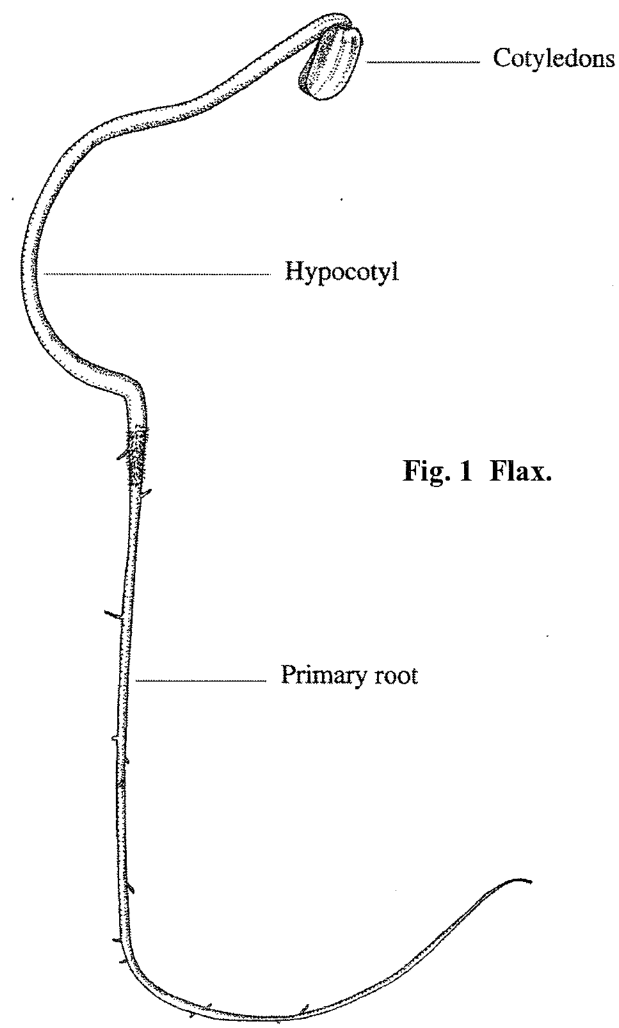


Fig. 1 Flax.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:
- missing (may be assumed to be present if cotyledons are intact).

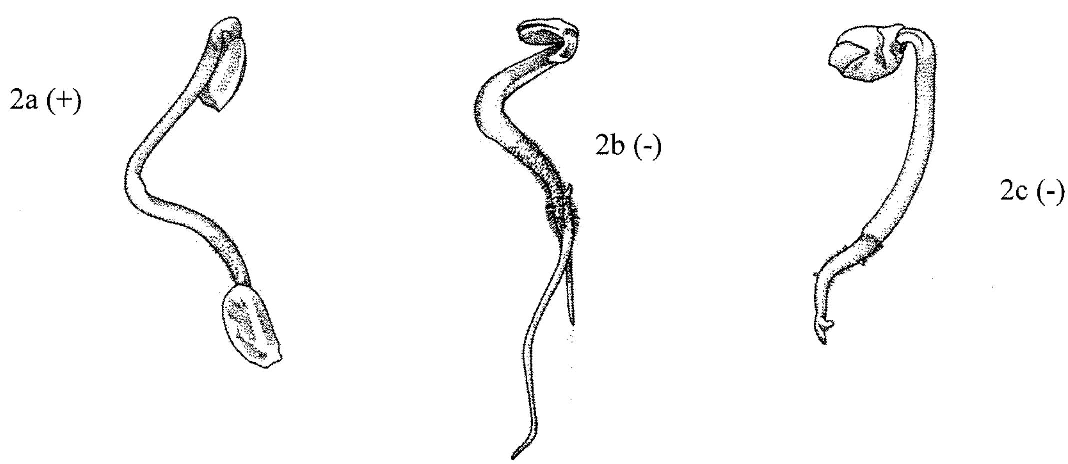
Hypocotyl:
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.

Root:
- none.
- weak, stubby or missing primary root with weak secondary roots.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. Due to the mucilaginous nature of the seed coat, seedlings germinated on blotters may adhere to the blotter and appear to be negatively geotropic.



2a. Root trapped in seed coat.

2b. Deep lesion in root.

2c. Stubby root.

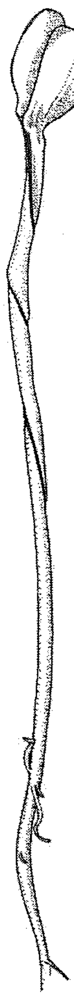
Fig. 2 Root defects.

Fig. 3 Hypocotyl defects.

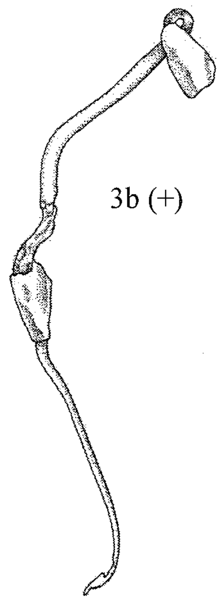
3a. Deep lesion, hypocotyl twisted.

3b. Seed coat trapped, causing hypocotyl damage and decay.

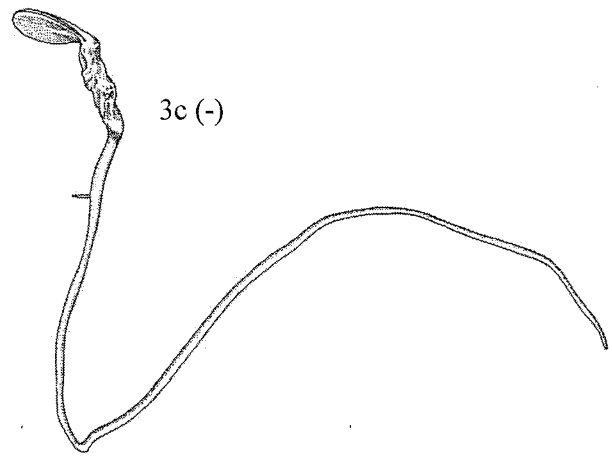
3c. Thickened grainy hypocotyl.



3a (-)

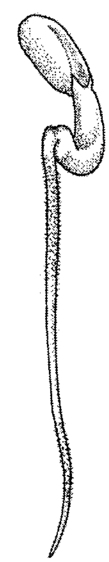


3b (+)



3c (-)

4b (-)



4a (-)

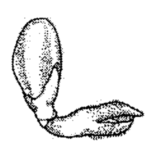


Fig. 4 Small seedlings.

4a. Short, thickened hypocotyl and root.

4b. Short, thickened hypocotyl.

MALVACEAE, MALLOW FAMILY

Abelmoschus esculentus, okra
Gossypium spp., cotton
Hibiscus cannabinus, kenaf

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons, which are much convoluted in the seed; they expand and become thin, leaf-like and photosynthetic.

Shoot system: The hypocotyl elongates carrying the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period. Areas of yellowish pigmentation may develop on the hypocotyl in cotton.

Root system: A primary root, with secondary roots usually developing within the test period. Areas of yellowish pigmentation may develop on the root in cotton.

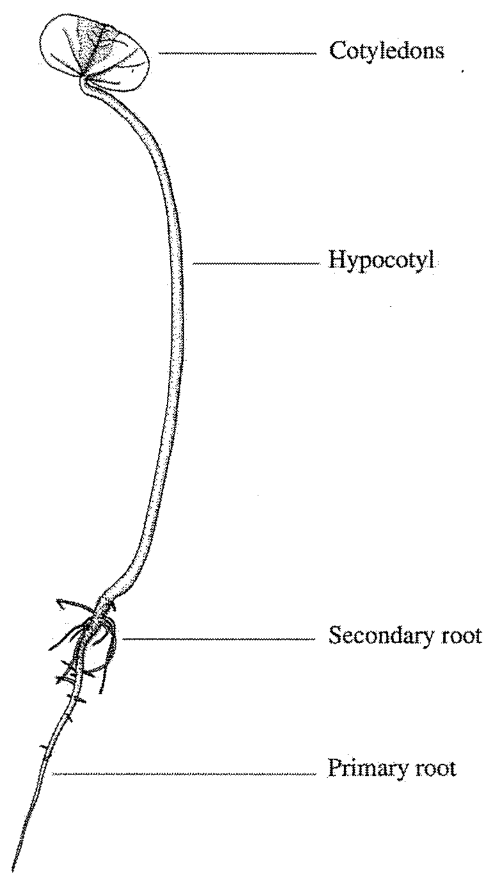


Fig. 1 Cotton.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay (see note 2).

Epicotyl:
- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl:
- deep open cracks or grainy lesions extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.

Root:
- none.
- weak, stubby or missing primary root with weak secondary or adventitious roots.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection (see note 1).
- albino.

NOTES

1. Seedlings with yellowish areas on the roots or hypocotyls of cotton are to be classified as normal, provided the cotyledons are free of infection. Seed coats must be removed from young seedlings to determine this.

2. Delinting of cotton by acid or flame may cause extensive damage to the cotyledons. The damaged cotyledons are very susceptible to decay and the seed coats may remain attached. It is essential that the cotyledons be freed from the seed coat so that the extent of damage can be evaluated.

3. For hard seeds, swollen seeds, and seeds that have just started to germinate, refer to Sec. 6.9 d (6) and Sec. 6.9 m (6) of the AOSA Rules Vol. 1.

2a. Intact seedling.

2b. Primary root missing, sufficient secondary roots.

2c. Primary root missing, insufficient secondary roots.

2d. Deep hypocotyl lesion.

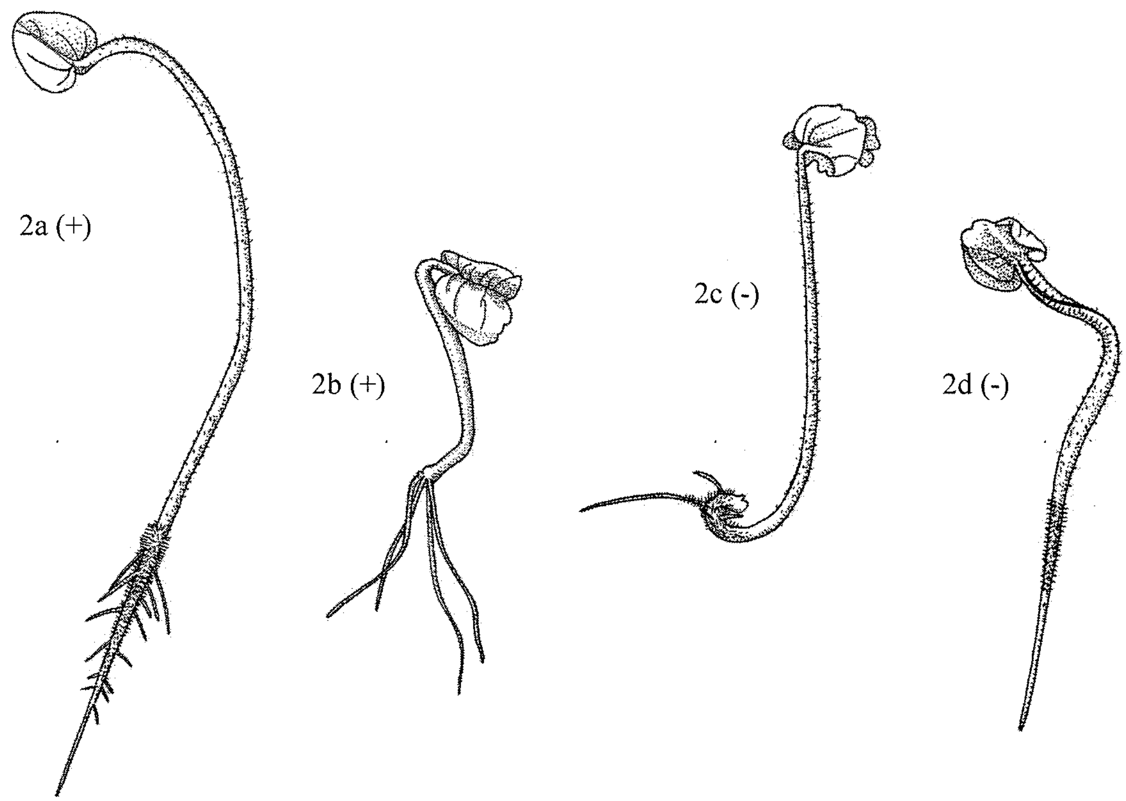


Fig. 2 Seedlings.

POACEAE, GRASS FAMILY I - Cereals

Avena sativa, oat
Hordeum vulgare subsp. *vulgare*, barley
Secale cereale subsp. *cereale*, rye
Secale strictum subsp. *strictum*, mountain rye
Triticum spp., wheat
×*Triticosecale* spp., triticale

GENERAL DESCRIPTION

Seedling type: Hypogeal monocot.

Food reserves: Endosperm. The scutellum is a modified cotyledon that is in direct contact with the endosperm. During germination the scutellum remains inside the seed absorbing nutrients from the endosperm and transferring them to the growing seedling.

Shoot system: The shoot consists of the coleoptile and enclosed leaves that grow from the meristematic region at their base and the mesocotyl. The shoot elongates and pushes through the soil surface; the mesocotyl may elongate depending on the variety and light intensity, but is usually not discernable. Splitting of the coleoptile tip occurs naturally as a result of expansion of the leaves inside.

Root system: A primary root and seminal roots. The primary root is not readily distinguishable from the seminal roots, therefore all roots arising from the seed are referred to as seminal roots.

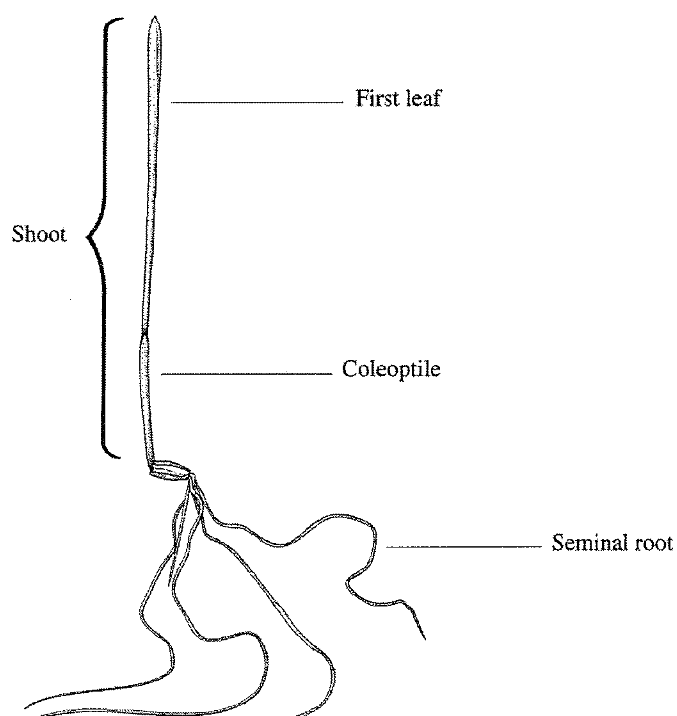


Fig. 1 Cereal.

ABNORMAL SEEDLING DESCRIPTION

Shoot:

- missing.
- no leaf.
- leaf extending less than halfway up into the coleoptile.
- leaf badly shredded or longitudinally split.
- coleoptile split for more than one-third the length from the tip.
- thin, spindly, pale or watery.
- badly frost-damaged (characterized by graininess, spiral twisting and shredding, and loss
- of vigor).
- deep open cracks in the mesocotyl.
- (see also notes 1 and 2).

Root:

- less than one strong seminal root.

Seedling:

- decayed at point of attachment to the scutellum.
- one or more essential structures impaired as a result of decay from primary infection.
- albino.
- endosperm obviously detached from the root-shoot axis (e.g. kernel lifted away by the growing shoot).
- seedlings with badly thickened and shortened roots and shoots due to injury from chemical treatment (see note 3).

NOTES

1. Seedlings grown in the dark or in low intensity light will exhibit increased elongation of the coleoptile and in some cases the mesocotyl. In towels, there may be considerable twisting of the shoot.

2. Splitting of the coleoptile tip occurs naturally as a result of expansion of the leaves inside and occurs after emergence and after the coleoptile ceases to elongate upon exposure to light.

3. Seedlings with badly thickened and shortened roots and shoots due to injury from chemical treatment are to be classified as abnormal. If such seedlings are difficult to evaluate on paper substrata, the interpretation should be based on the seedling performance in sand or soil.

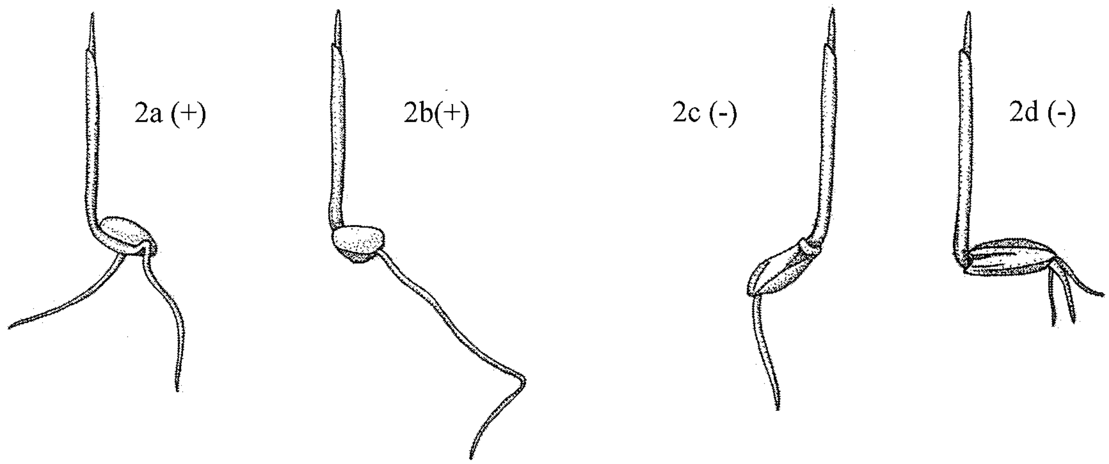


Fig. 2 Root defects.

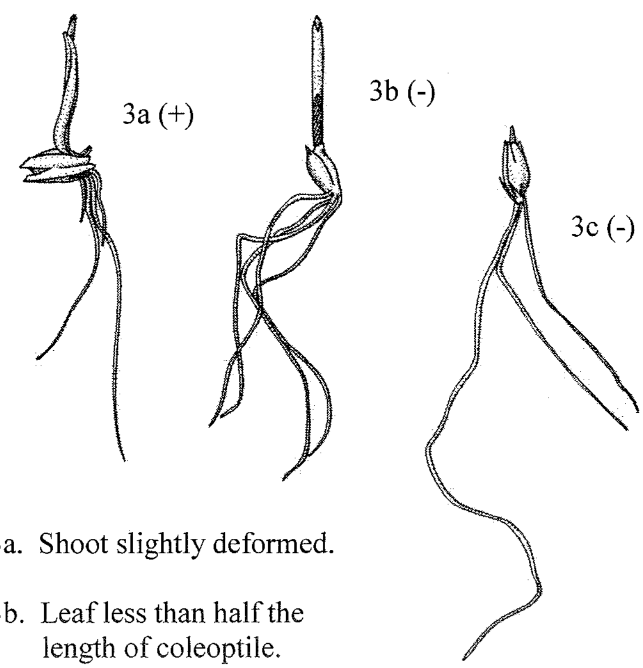
2a. Two strong seminal roots.

2b. One strong seminal root.

2c. Less than one strong seminal root.

2d. Less than one strong seminal root.

Fig. 3 Shoot defects.



3a. Shoot slightly deformed.

3b. Leaf less than half the length of coleoptile.

3c. Shoot not developing.

Fig. 4 Detached endosperm.

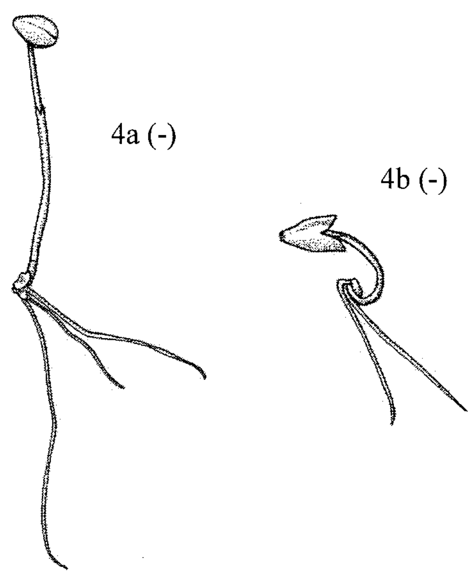
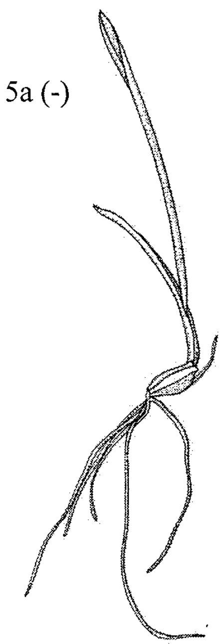
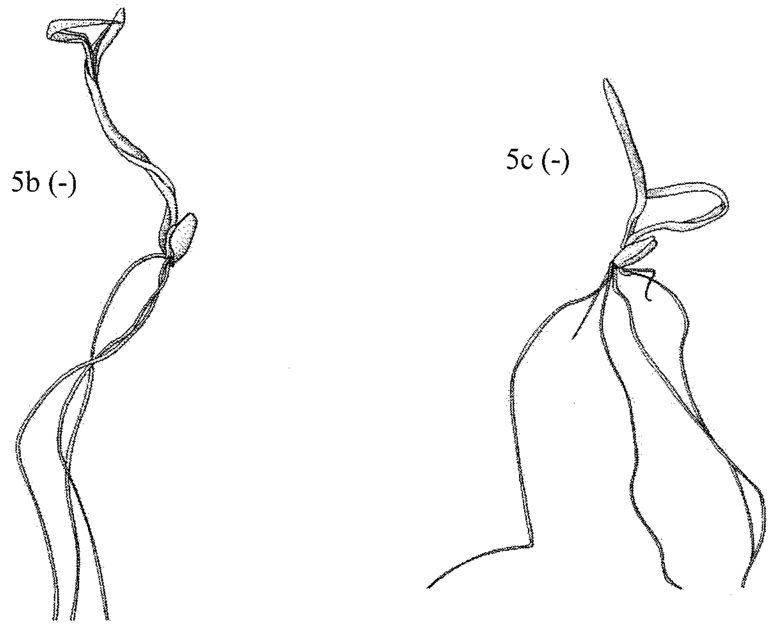


Fig. 5 Leaf defects.

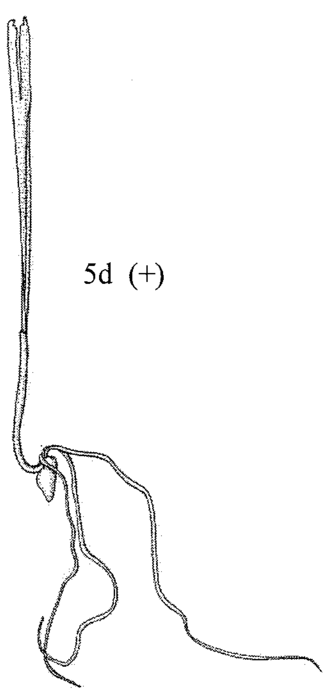


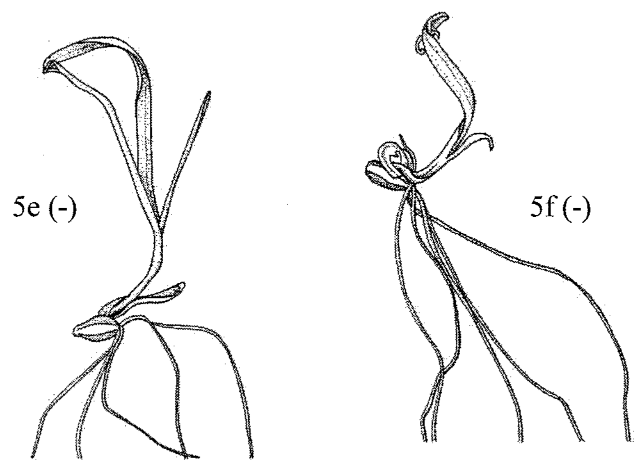


5a. Coleoptile split for more than one-third of the length from the tip.

5b. Coleoptile damaged with leaf emerging through side split.

5c. Coleoptile split near base, with leaf bursting out.

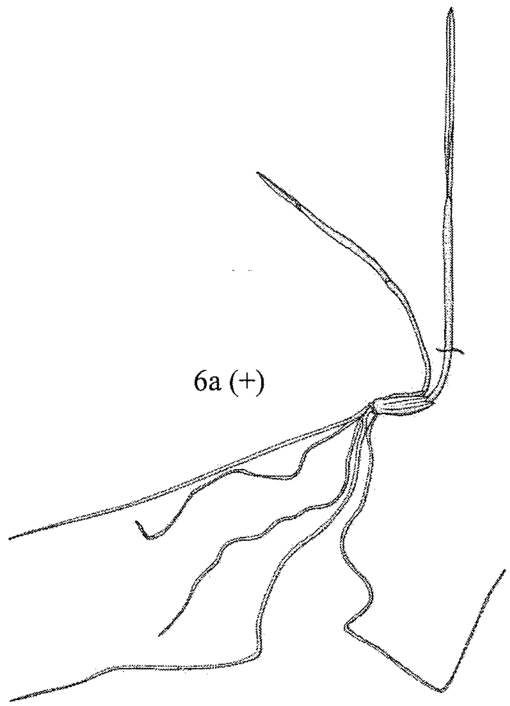




5d. Leaf tip split, but shoot otherwise healthy.

5e. First leaf badly split

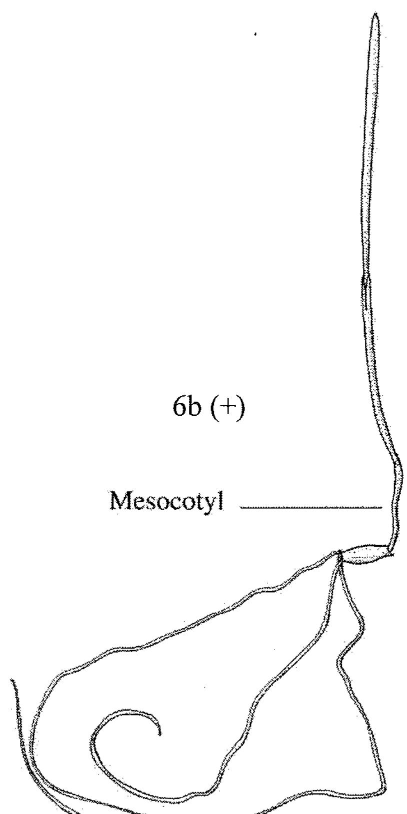
5f. Leaf shredded.



6a. Double oat.

6b. Seedling with elongated mesocotyl. Note that this gives the seedling the appearance of being “spindly”.

6c. Spiraling shoot, from being trapped in confined space such as towel or closely planted seeds.



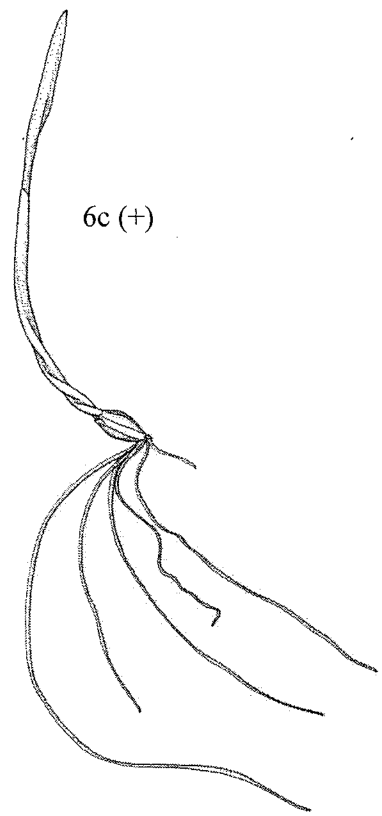


Fig. 6 Seedlings.

POACEAE, GRASS FAMILY II - Rice

Oryza sativa, rice

GENERAL DESCRIPTION

Seedling type: Hypogeal monocot.

Food reserves: Endosperm. The scutellum is a modified cotyledon that is in direct contact with the endosperm. During germination the scutellum remains inside the seed absorbing nutrients from the endosperm and transferring them to the growing seedling.

Shoot system: The shoot consists of the coleoptile and enclosed leaves that grow from the meristematic region at their base and the mesocotyl. The shoot elongates and pushes through the soil or water surface; the mesocotyl may elongate depending on the variety and environmental conditions. Splitting of the coleoptile occurs naturally as a result of expansion of the leaves inside.

Root system: Strong primary root and seminal roots. Adventitious roots may start to develop from the mesocotyl or coleoptilar node within the test period. If the mesocotyl elongates the adventitious roots will be carried above the grain.

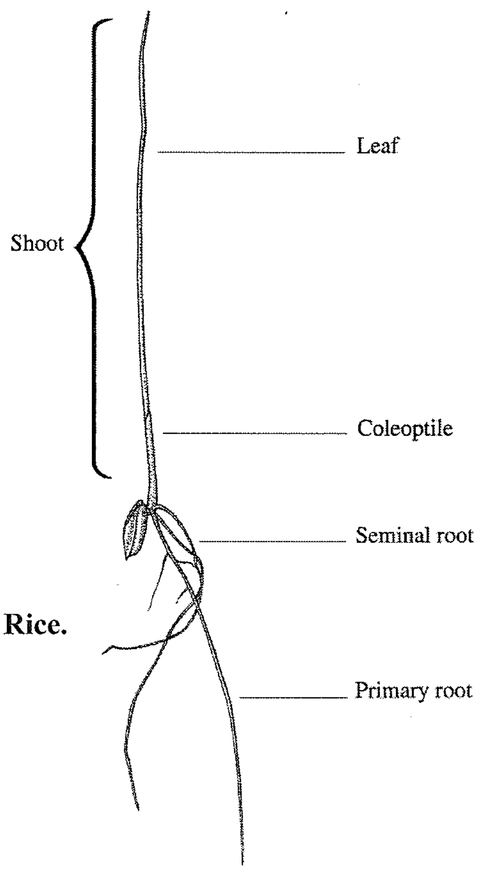


Fig. 1 Rice.

ABNORMAL SEEDLING DESCRIPTION

Shoot:

- missing.
- no leaf.
- leaf extending less than halfway up into the coleoptile.
- leaf badly shredded or longitudinally split.
- thin, spindly, pale or watery (in comparison with other seedlings in the test).
- deep open cracks in the mesocotyl.
- (see note 1).

Root:

- none.
- weak primary root with insufficient seminal or adventitious roots.

Seedling:

- decay at point of attachment to the scutellum.
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

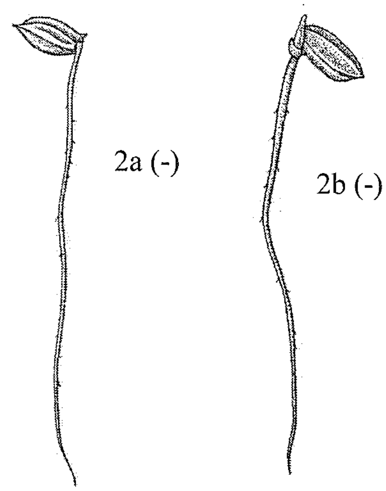
NOTES

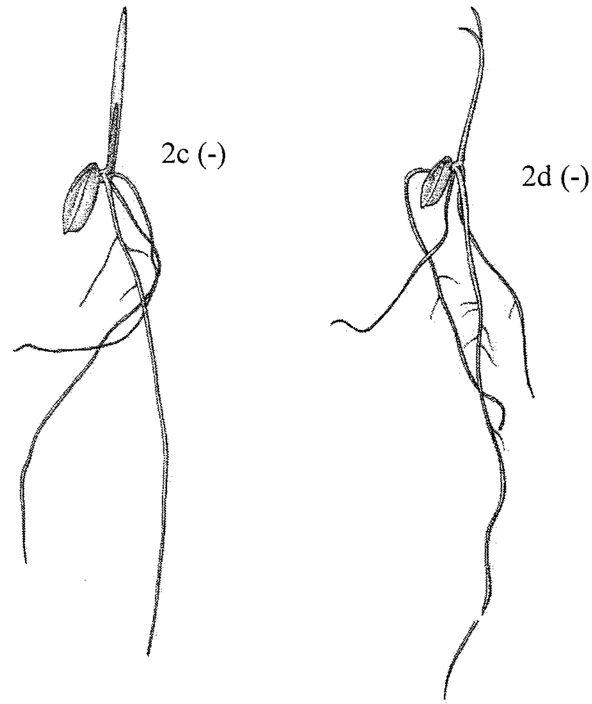
1. Fungal development may cause variation in test results; more uniform results will be obtained if seeds are well spaced or grown in sand or soil. The "flood test" may also be used: The seed is planted in moist sand. On the seventh day of test add water to a depth of one-quarter inch above the sand level and leave for the remainder of the test period. Only a final count is made. (See Sec. 6.8 h of the AOSA Rules Vol. 1.)

2. Preliminary counts should not be made until the 5th to 7th day, since the shoot is not sufficiently developed to evaluate earlier.

3. Splitting of the coleoptile occurs naturally as a result of expansion of the leaves inside. The condition of the coleoptile is not to be considered as an evaluation factor on its own; however, damage to the coleoptile is a signal that the other shoot structures should be examined closely to determine if they have been damaged.

Fig. 2 Shoot defects.





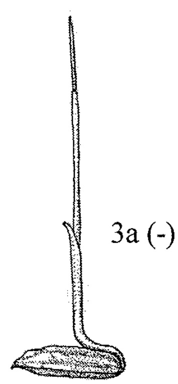
2a. Missing shoot.

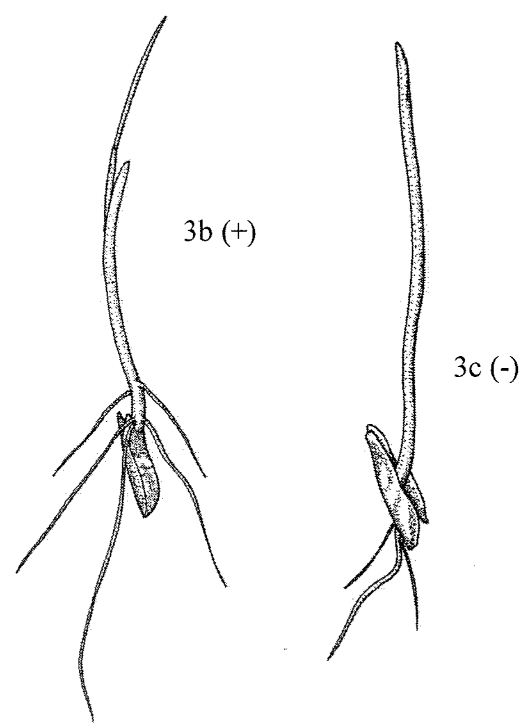
2b. Empty coleoptile.

2c. Leaf less than half the length of coleoptile.

2d. Thin, spindly shoot.

Fig. 3 Root defects.





3a. No roots.

3b. No primary root with sufficient seminal roots.

3c. Weak, short primary root with insufficient seminal roots.

POACEAE, GRASS FAMILY III - Corn

Zea mays, corn

GENERAL DESCRIPTION

Seedling type: Hypogeal monocot.

Food reserves: Endosperm. The scutellum is a modified cotyledon that is in direct contact with the endosperm. During germination the scutellum remains inside the seed absorbing nutrients from the endosperm and transferring them to the growing seedling.

Shoot system: The shoot consists of the coleoptile and enclosed leaves that grow from the meristematic region at their base and the mesocotyl. The shoot elongates and pushes through the soil surface. The mesocotyl usually elongates. Splitting of the coleoptile occurs naturally as a result of expansion of the leaves inside.

Root system: Strong primary root and seminal roots. Adventitious roots may start to develop from the mesocotyl or coleoptilar node within the test period.

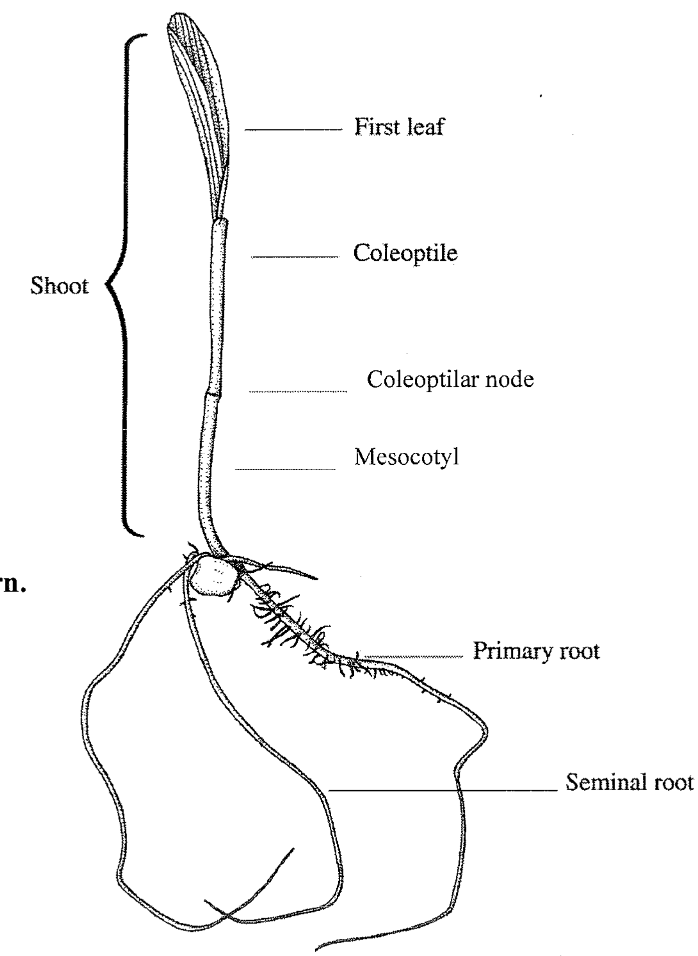


Fig. 1 Corn.

ABNORMAL SEEDLING DESCRIPTION

Shoot:

- missing.
- no leaf.
- leaf and coleoptile proportionality:
  --Field corn: no evident growth of enclosed leaves that grow from the meristematic region at their base and the mesocotyl (see note 3a).
  --Sweet corn, popcorn and ornamental corn: leaf extending less than halfway up into the coleoptile (see note 3b).
- leaf badly shredded or longitudinally split (see note 1).
- if the first leaf has emerged at time of evaluation, seedling is abnormal if the coleoptile has any of the following defects **together with** damage to the first leaf as defined in Figure 7. (See figure 7 and note 2.):
  --coleoptile split for more than one-third of the length from the tip.
  --coleoptile strongly bent over.
  --coleoptile tip damaged or missing.
  --coleoptile split at any location below the tip.
- if first leaf has not emerged at time of evaluation (see note 2):
  --tip of coleoptile damaged or missing.
  --coleoptile split for more than one-third of the length from the tip.
- leaf protruding below the tip of the coleoptile.
- thin, spindly, pale or watery.
- deep open cracks in the mesocotyl.

Root:

- none.
- weak, stubby or missing primary root with weak seminal roots.

Seedling:

- decayed at point of attachment to the scutellum.
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. Seedlings grown in the dark or in low intensity light will exhibit increased elongation of the coleoptile and mesocotyl. In towels, there may be considerable twisting of the shoot system. Overcrowding may cause splitting of the coleoptile and leaves.

2. Occasionally in the sand test and often in the rolled towel test, the leaf will not have emerged through the tip of the coleoptile by the end of the full germination period (7 days). If the leaf has not emerged at the time of final evaluation, seedlings with a split in the coleoptile for more than one-third of the length from the tip and seedlings with the coleoptile tip missing or damaged must be classed abnormal. An exception to this rule may be made when it is clearly evident that the splitting is due to pressure caused by restricted growth within the substrate. When the first leaf has emerged through the tip of the coleoptile at the time of evaluation, it is possible to use damage to the leaf as evidence that damage to the coleoptile is significant. Seedlings with the coleoptile defects described in Figure 7a, may

be classed as normal when the first leaf is intact or only slightly damaged as defined in Figure 7b.

3. Leaf and coleoptile proportionality:
   a. Field corn: Any evident growth of the enclosed leaves that grow from the meristematic region at their base and the mesocotyl. If there is no growth evident, it is likely that the primordial leaves have been damaged.
   b. Sweet corn, popcorn and ornamental corn: When determining whether or not the leaf has attained half the length of the coleoptile or more, the measurement is to be taken from the base of the coleoptile (coleoptilar node) and not necessarily from the base of the shoot (that may include an elongated mesocotyl).

4. A twisted and curled shoot bound by a tough seed coat may be considered normal.

5. Seedlings from frost-damaged seeds may be characterized by grainy coleoptiles and spirally twisted leaves as well as decay at the point of attachment to the scutellum.

6. Flat seeds germinate faster than round seeds. It may be necessary to extend the test by two days for round seeds.

7. At day seven (or after if the test is extended due to the presence of smaller seedlings) the shoot and root each should be at least be as long as the kernel (see note 8). It is desirable for the shoot and root to be in proportion.

8. Slower developing seedlings with a short shoot and a longer root should be examined carefully to determine if the shoot is short because of damage or because it is a characteristic of the seed lot (i.e. inbred, tough pericarp) or due to test conditions.

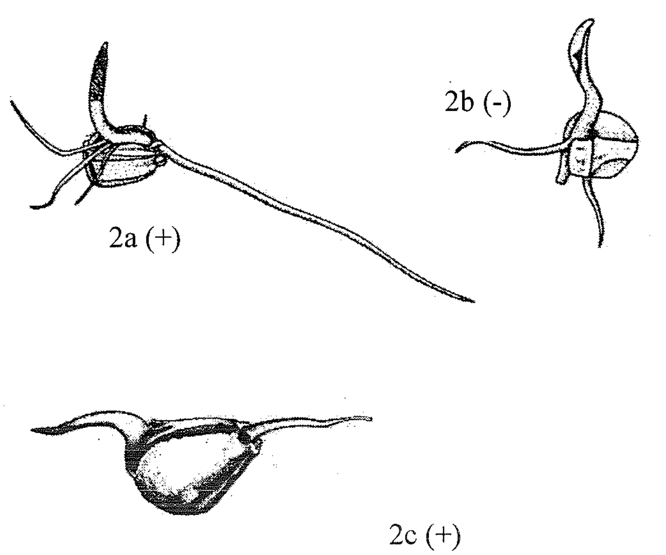


Fig. 2 Small seedlings.

2a. Late-germinating seedling (at final count; see 3.5.1.b).

2b. Shoot damaged and weak roots.

2c. Shoot and root the length of the kernel.

Fig. 3 Split leaves.

3a. Leaf damaged, coleoptile tip damaged (see also Fig. 7).
3b. Leaf badly split.
3c. Leaf shredded.
3d. Leaf damaged.

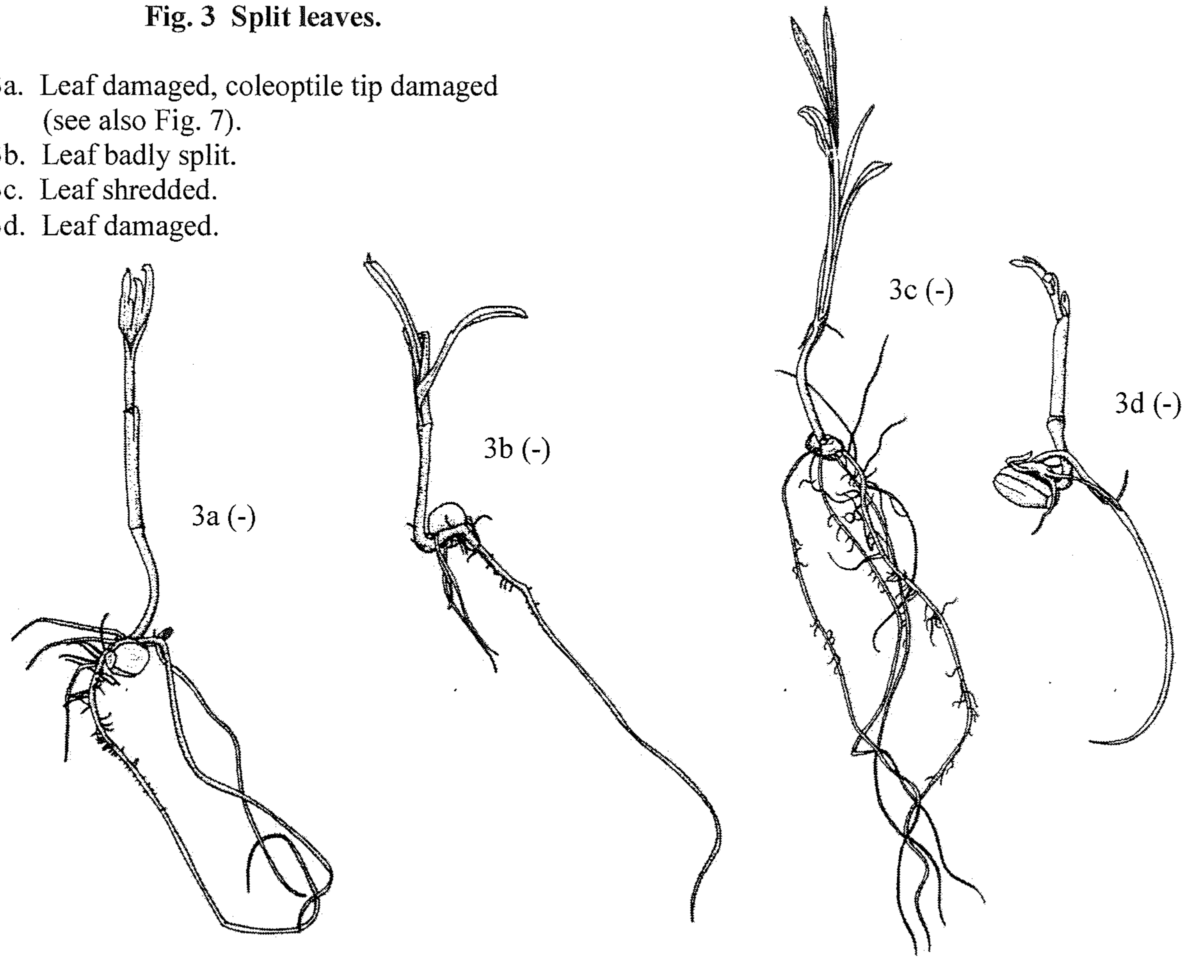


Fig. 4 Shoot defects.

4a. Coleoptile split, but seedling otherwise healthy.

4b. coleoptile split, leaf curled due to test conditions.

4c. Leaf emerged from base of coleoptile.

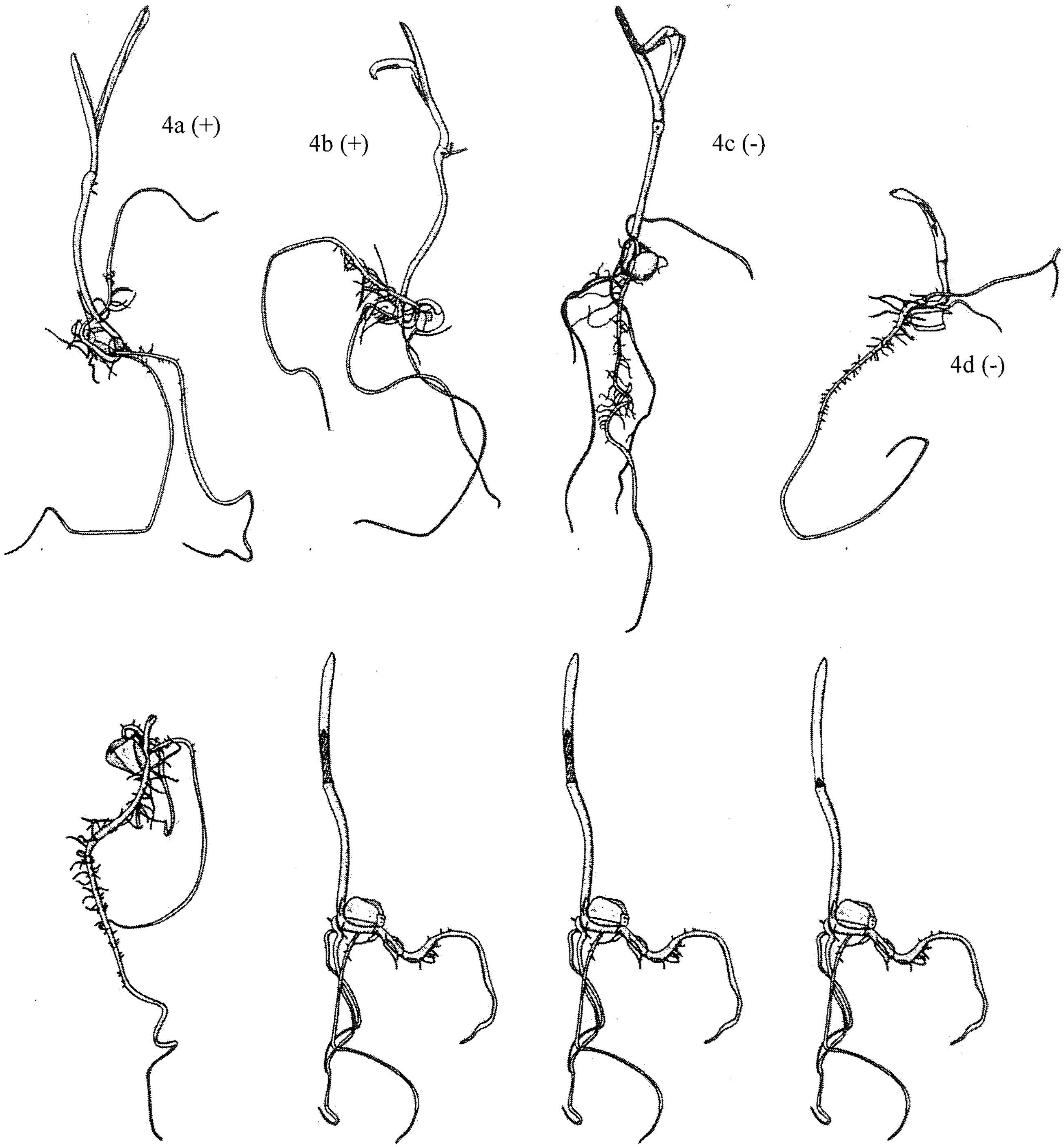
4d. Damaged coleoptile with shredded leaf.

4e. Shoot damaged and not developing.

$4f_1$. Leaf less than half the length of coleoptile (field corn).

$4f_2$. Leaf less than half the length of coleoptile (sweet corn, popcorn and ornamental corn).

4g. Leaf meristematic tissue present or absent, but no evident growth of leaves in the coleoptile



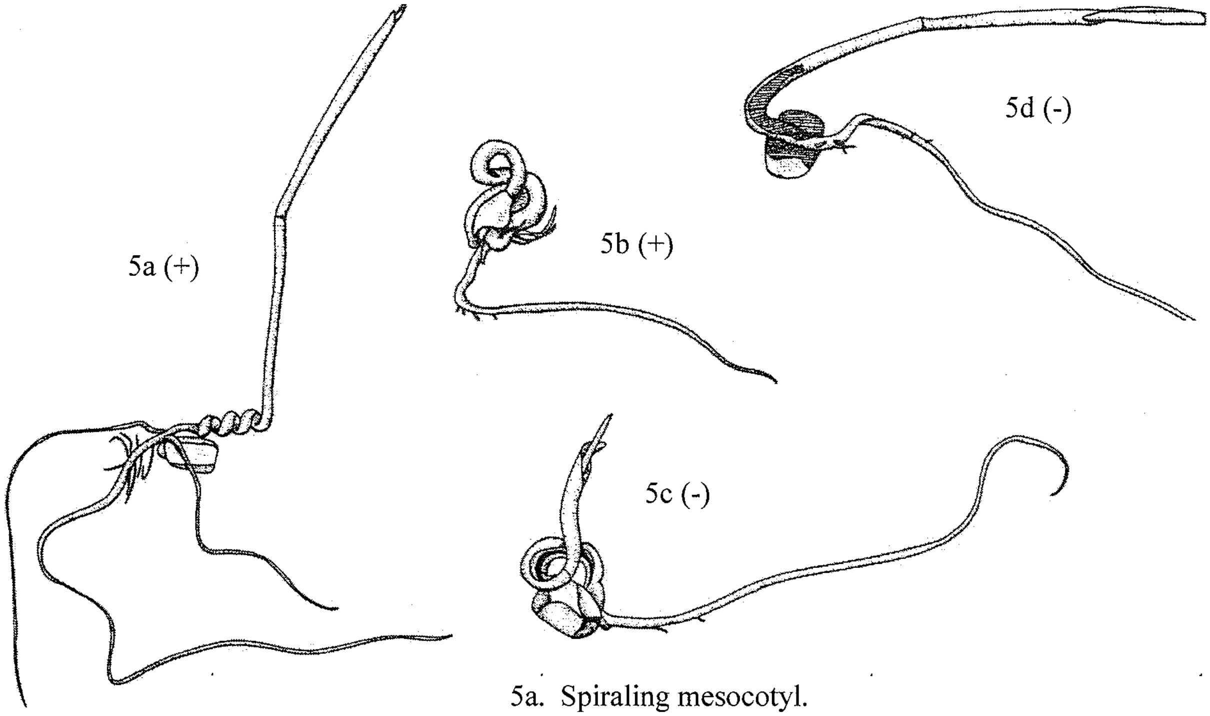
4e (-)

$4f_1$ (+) Field corn

$4f_2$ (-) Sweet corn, popcorn and ornamental corn

4g(-)

Fig. 5 Mesocotyl defects.



5a. Spiraling mesocotyl.

5b. Shoot trapped in seed coat, but otherwise healthy.

5c. Deep mesocotyl lesion.

5d. Decay at point of attachment to scutellum.

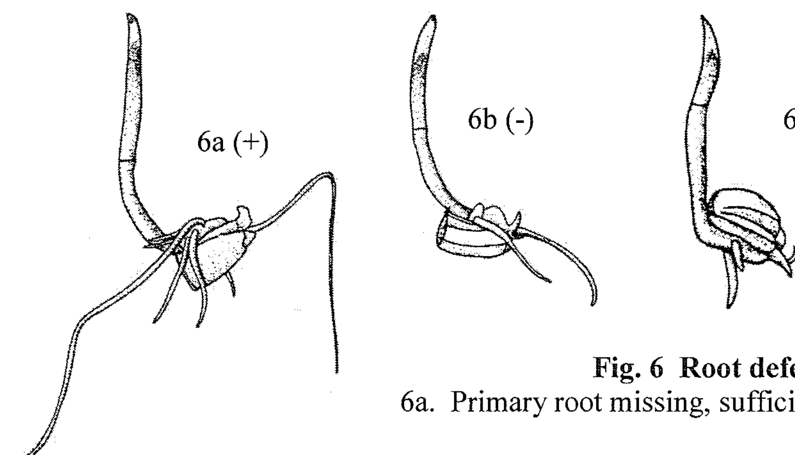


Fig. 6 Root defects.

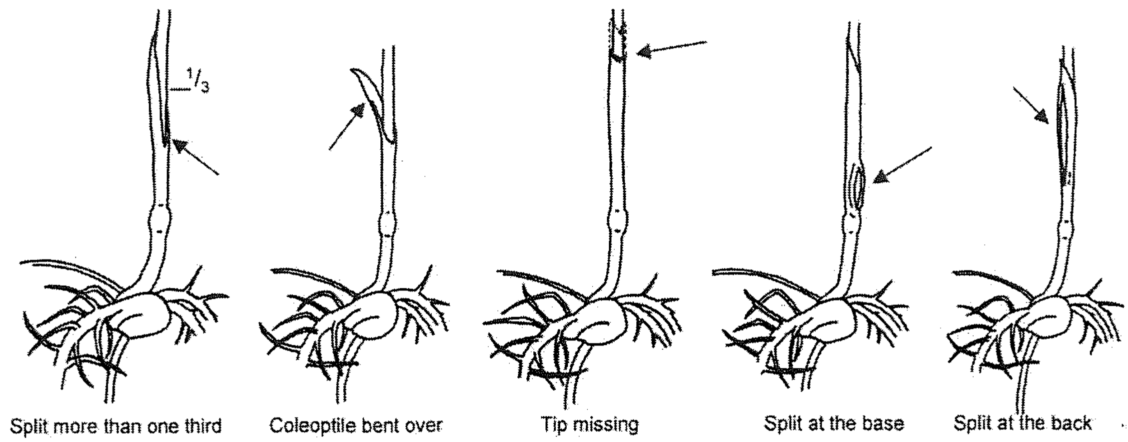
6a. Primary root missing, sufficient seminal roots.

6b. Primary root missing, insufficient seminal roots.

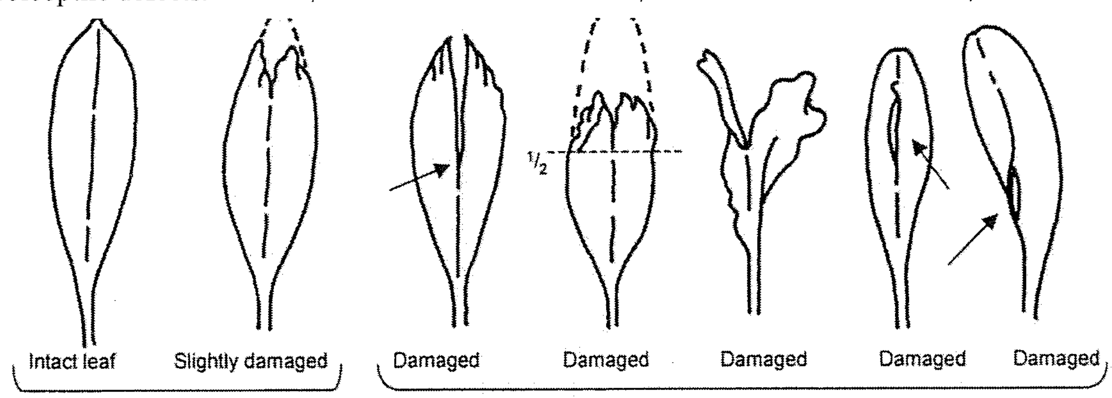
6c. Insufficient roots.

Fig. 7 Coleoptile defects.

7a. Seedlings are normal if the first leaf is intact or only slightly damaged, as defined in Figure 7b. Seedlings are abnormal if first leaf is damaged, as defined in Figure 7b.



7b. Definition of intact, slightly damaged and damaged first leaf, for evaluation of seedlings with coleoptile defects.



Seedlings with Fig. 7a defects classed Normal

Seedlings with Fig. 7a defects classed Abnormal

REFERENCES

Davis, G. N. and R. H. Porter. 1936. Comparative absorption of water by endosperm and embryo of corn kernels. Proc. Assoc. Off. Seed Anal., 62-67.

Shieh, W. J. and M. B. McDonald. 1982. The influence of seed size, shape and treatment on inbred seed corn quality. Seed Sci. and Technol., 10:307-313.

POACEAE, GRASS FAMILY IV - Sorghum

Sorghum hybr., 'sorgrass'
Sorghum bicolor subsp. *bicolor*, sorghum
Sorghum halepense, johnsongrass
Sorghum ×almum, almum sorghum
Sorghum bicolor nothosubsp. *drummondii*, sudangrass and sorghum-sudangrass

GENERAL DESCRIPTION

Seedling type: Hypogeal monocot.

Food reserves: Endosperm. The scutellum is a modified cotyledon that is in direct contact with the endosperm. During germination the scutellum remains inside the seed absorbing nutrients from the endosperm and transferring them to the growing seedling.

Shoot system: The shoot consists of the coleoptile and enclosed leaves that grow from the meristematic region at their base and the mesocotyl. The shoot elongates and pushes through the soil surface; the mesocotyl usually elongates. Areas of natural, reddish pigmentation may develop on the mesocotyl and coleoptile. Splitting of the coleoptile occurs naturally as a result of expansion of the leaves inside.

Root system: A long primary root, usually with secondary roots developing within the test period. Adventitious roots arising from the mesocotyl and coleoptilar node may start development within the test period. Areas of natural, reddish pigmentation may develop on the root.

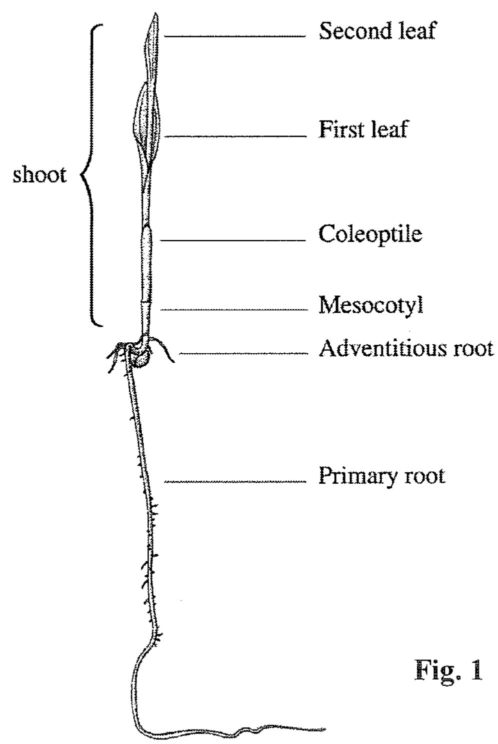


Fig. 1 Sorghum.

ABNORMAL SEEDLING DESCRIPTION

Shoot:
- missing.
- no leaf.
- leaf extending less than halfway up into the coleoptile.
- leaf badly shredded or longitudinally split.
- thin, spindly, pale or watery (in comparison with other seedlings in the test).
- deep open cracks in the mesocotyl.
- (see notes 1, 2 and 3).

Root:
- none.
- damaged or weak primary root with less than two strong secondary roots.

Seedling:
- decayed at point of attachment to the scutellum.
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. Splitting of the coleoptile occurs naturally as a result of expansion of the leaves inside. The condition of the coleoptile is not to be considered as an evaluation factor on its own; however, damage to the coleoptile is a signal that the other shoot structures should be examined closely to determine if they have been damaged.

2. Seedlings with red coloration on or in the roots or coleoptiles caused by natural pigmentation are to be considered normal.

3. Seedlings from frost-damaged seeds may be characterized by grainy coleoptiles and spirally twisted leaves as well as decay at the point of attachment to the scutellum.

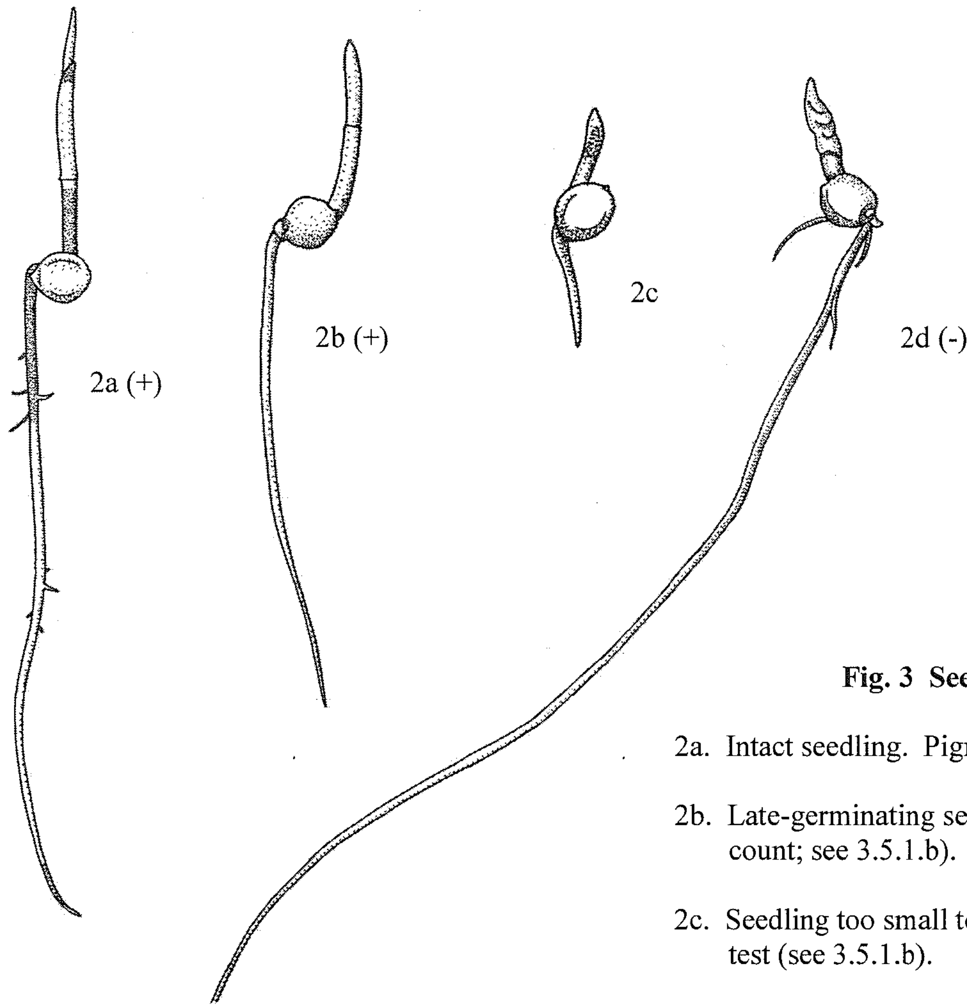


Fig. 3 Seedlings.

2a. Intact seedling. Pigmentation normal.

2b. Late-germinating seedling (at final count; see 3.5.1.b).

2c. Seedling too small to evaluate; extend test (see 3.5.1.b).

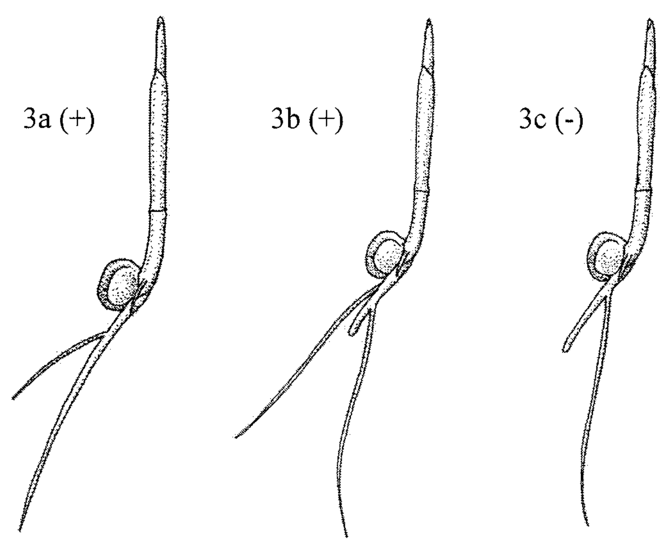
2d. Deformed grainy shoot.

Fig. 3 Root defects.

3a. Primary root long enough.

3b. Stubby primary root, with sufficient secondary roots.

3c. Stubby primary root, with insufficient secondary roots.



POACEAE, GRASS FAMILY V - Other kinds

All grass species listed in the Rules, other than barley, corn, oats, rice, rye, sorghum, triticale and wheat.

GENERAL DESCRIPTION

Seedling type: Hypogeal monocot.

Food reserves: Endosperm. The scutellum is a modified cotyledon that is in direct contact with the endosperm. During germination the scutellum remains inside the seed absorbing nutrients from the endosperm and transferring them to the growing seedling.

Shoot system: The shoot consists of the coleoptile and enclosed leaves that grow from the meristematic region at their base and the mesocotyl. The shoot elongates and pushes through the soil surface. The mesocotyl usually does not elongate significantly in most species, but may in some (e.g. tall oatgrass). Splitting of the coleoptile occurs naturally as a result of expansion of the leaves inside.

Root system: At the beginning of germination, the radicle breaks through the coleorhiza and seed coat and develops into a long primary root. Secondary or adventitious roots usually do not develop within the test period.

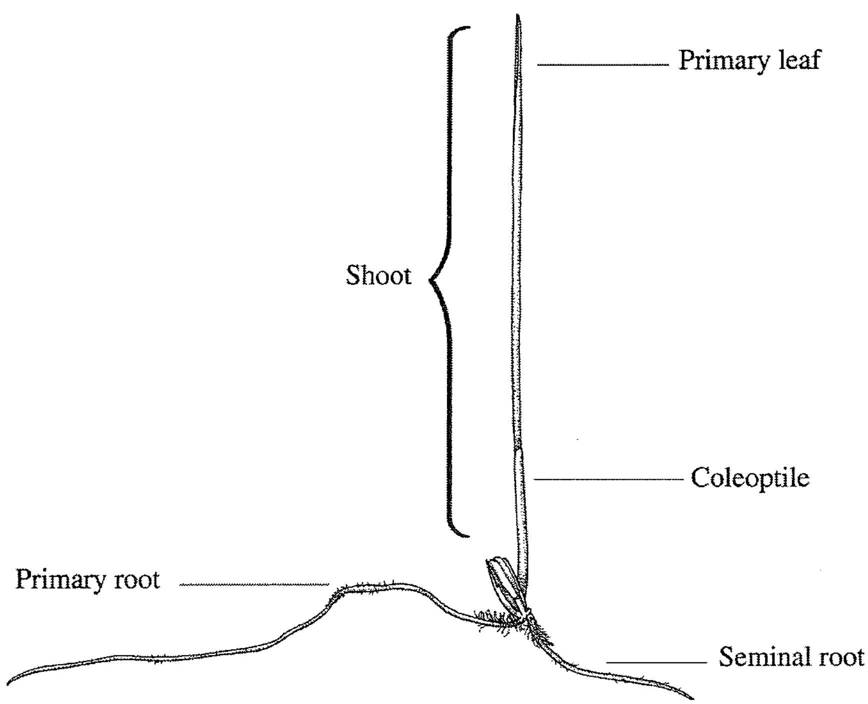


Fig. 1 Ryegrass.

ABNORMAL SEEDLING DESCRIPTION

Shoot:
- missing.
- short, thick and grainy.
- no leaf.
- leaf extending less than halfway up into the coleoptile.
- leaf badly shredded or longitudinally split.
- thin, spindly, pale or watery.
- deep open cracks in the mesocotyl.
- (see also notes 3 and 6)

Root:
- missing or defective primary root even if other roots are present (see note 2).
- spindly, stubby or watery primary root (see note 1; for Kentucky bluegrass, see note 5).

Seedling:
- decayed at point of attachment to the scutellum.
- one or more essential structures impaired as a result of decay from primary infection.
- albino.
- yellow (when grown in light).
- endosperm obviously detached from the root-shoot axis (e.g. kernel lifted away by the growing shoot).

NOTES

1. The use of a potassium nitrate solution is recommended for breaking dormancy in certain species (see Table 6A of the AOSA Rules Vol. 1). Its use may cause shortened roots and promote fungal growth. Retests on top of soil in closed petri dishes are recommended to aid in interpretation of short roots that appear to be caused by the use of potassium nitrate.

2. In certain species (e.g. bermudagrass) the primary root may not be readily visible because it is coiled inside the tightly fitting lemma and palea. At the time of evaluation, the glumes should be removed and the root observed. Such seedlings are to be classified as normal if the root has developed.

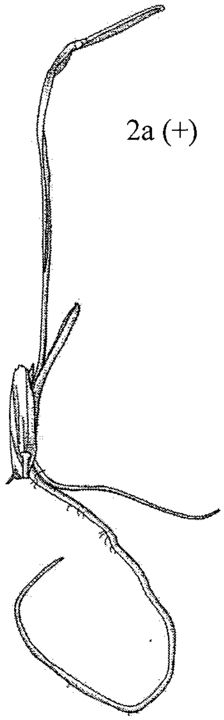
3. Splitting of the coleoptile occurs naturally as a result of expansion of the leaves inside. The condition of the coleoptile is not to be considered as an evaluation factor on its own; however, damage to the coleoptile is an indication that the other shoot structures should be examined closely to determine if they have been damaged.

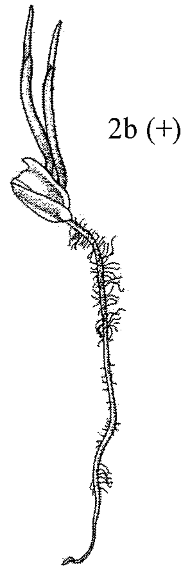
4. The temperature alternations and prechilling treatments listed in the rules are specific. It is stressed that lack of correct temperature control may cause grass seeds to exhibit erratic germination, to show no growth at all or to cause secondary dormancy.

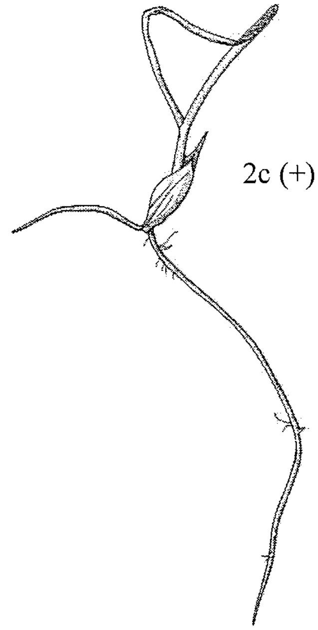
5. For Kentucky bluegrass, seedlings with a primary root 1/16 inch or more in length are to be classified as normal.

6. Seedlings from frost-damaged seeds may be characterized by grainy coleoptiles and spirally twisted leaves as well as decay at the point of attachment to the scutellum.

Fig. 2 Shoot defects.







2a. Coleoptile split and leaf wrinkled, shoot otherwise healthy.

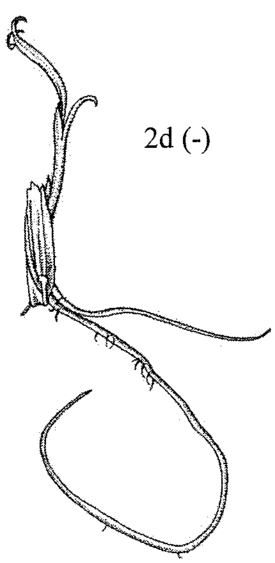
2b. Double shoot.

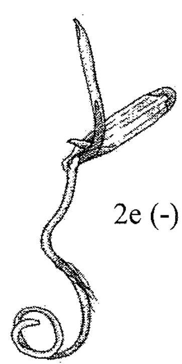
2c. Coleoptile split below the tip and leaf busting out.

2d. Badly split or shredded leaf.

2e. Leaf less than half the length of the coleoptile.

2f. Short grainy shoot.





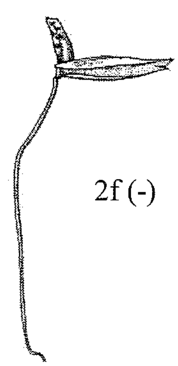
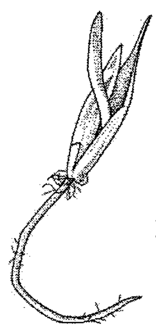


Fig. 3 Root defects.

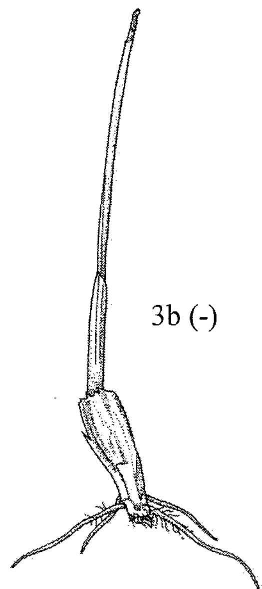
3a. Late-germinating seedling (at final count; see 3.5.1.b).

3b. Missing primary root (note shriveled leaf tip).

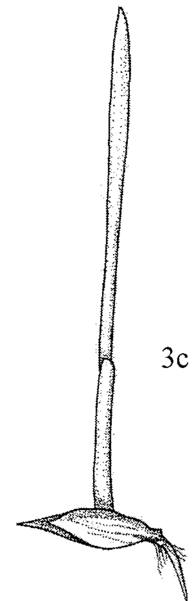
3c. Stubby primary root.



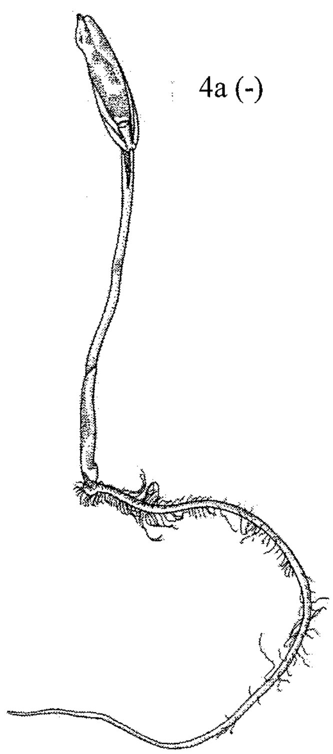
3a (+)



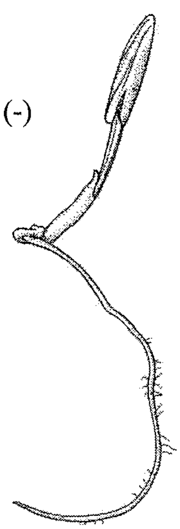
3b (-)



3c (-)



4a (-)



4b (-)

Fig. 4 Detached endosperm.

4a. Endosperm detached from the root-shoot axis and seedling strong.

4b. Endosperm detached from the root-shoot axis and seedling weak.

POLYGONACEAE, KNOTWEED FAMILY

Fagopyrum esculentum, buckwheat
Rheum × *rhabarbarum*, rhubarb
Rumex acetosa, sorrel

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons, starchy endosperm.

Shoot system: The hypocotyl elongates carrying the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A primary root with secondary roots developing within the test period for some species.

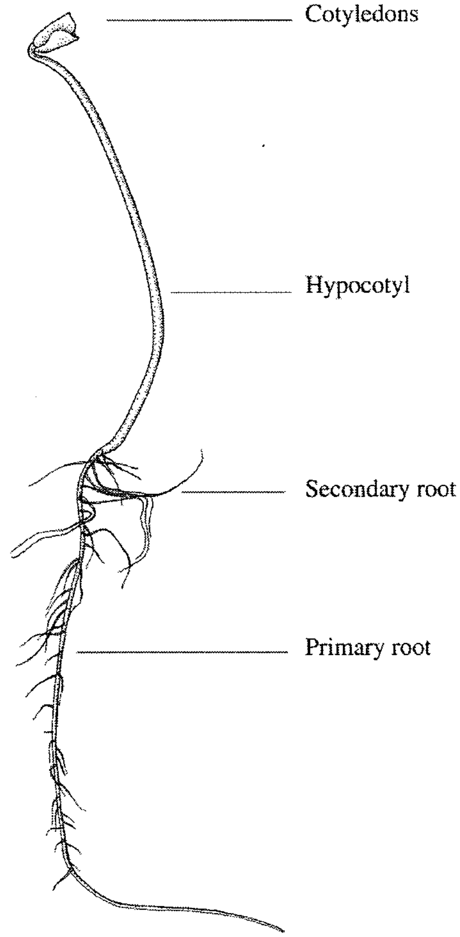


Fig. 1 Buckwheat.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

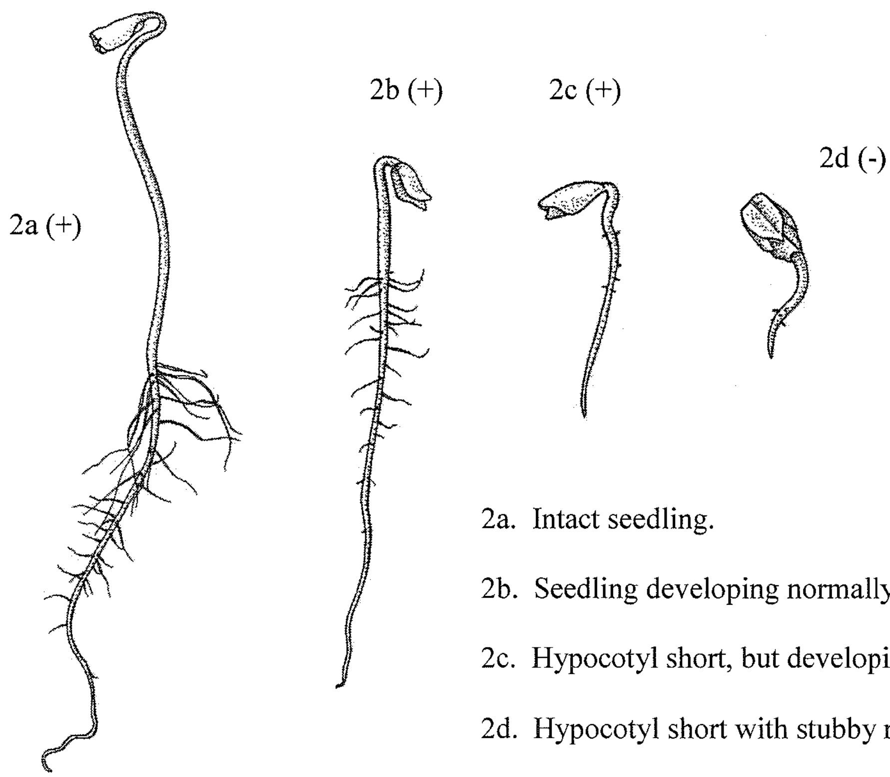
Epicotyl:
- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl:
- deep open cracks or grainy lesions extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.

Root:
- none.
- weak, stubby or missing primary root with weak secondary or adventitious roots.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

Fig. 2 Small seedlings.



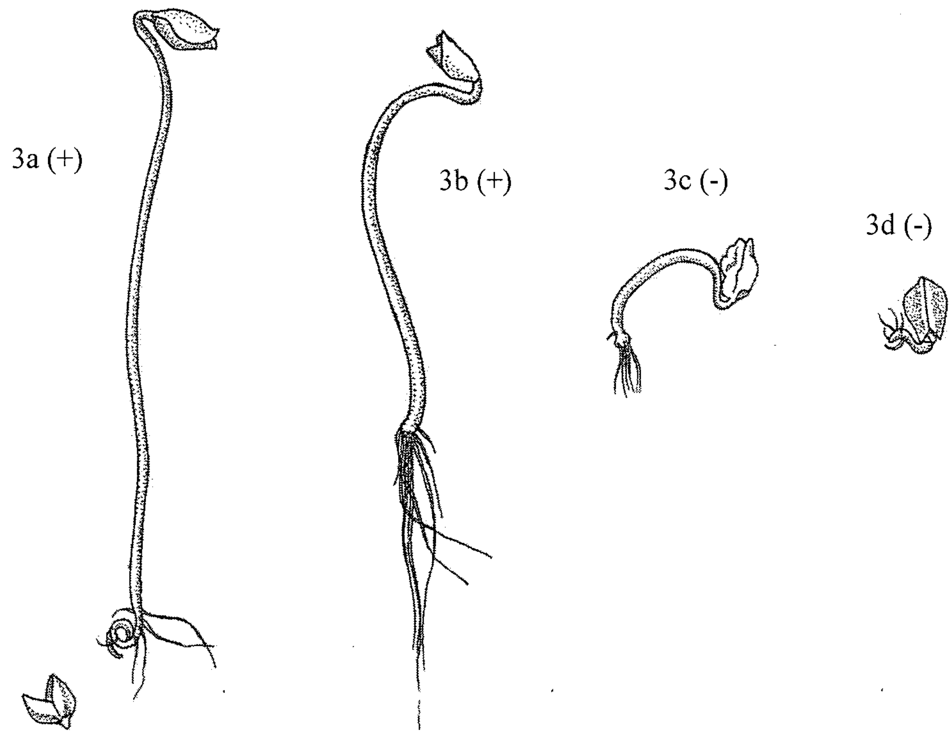
2a. Intact seedling.

2b. Seedling developing normally.

2c. Hypocotyl short, but developing normally.

2d. Hypocotyl short with stubby root.

Fig. 3 Root defects.

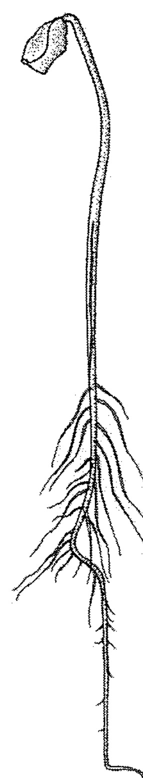


3a. Root coiled inside seed coat.

3b. Primary root damaged or missing, sufficient secondary or adventitious roots.

3c. Insufficient roots.

3d. Insufficient roots and short hypocotyl.



4 (-)

Fig. 4 Deep hypocotyl lesion (see 3.5.9).

PRIMULACEAE, PRIMROSE FAMILY I - Cyclamen

Cyclamen africanum, cyclamen

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Fleshy endosperm; minor reserves in the cotyledon.

Shoot system: Swollen tuberous hypocotyl and a single cotyledon (normally there is no second cotyledon) borne on a petiole, the terminal bud lying at its base.

Root system: Several seminal roots, developing more or less simultaneously at the distal end of the hypocotyl.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- cotyledon petiole broken or split (see note 2).

Epicotyl:
- missing (may be assumed to be present if cotyledon petiole is intact).

Hypocotyl:
- not forming a tuber.
- split, constricted, spindly, glassy.

Root:
- none, or only one seminal root.
- stunted or stubby.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. The cotyledon petiole should be examined at the point of entry into the seed coat for signs of decay.

2. Normally there is no second cotyledon. The dark green, heart-shaped blade of the single cotyledon is not usually evident during the prescribed test period.

REFERENCES

Bekendam, J. and R. Grob. 1979. Handbook for Seedling Evaluation, Second Edition. International Seed Testing Association, Zurich, Switzerland.

PRIMULACEAE, PRIMROSE FAMILY II, Kinds other than Cyclamen

Anagallis arvensis, scarlet pimpernel
Anagallis monelli, anagallis
Primula spp., primrose

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Leaf-like cotyledons and endosperm.

Shoot system: The hypocotyl elongates carrying the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A primary root.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue remaining free of necrosis or decay.
- seed coat tightly adhering to cotyledons.

Epicotyl:
- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl:
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.
- watery.

Root:
- weak, stubby or missing primary root (secondary roots will not compensate for a defective primary root).
- primary root tip blunt.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

SCROPHULARIACEAE, FIGWORT FAMILY

[Preferred family names according to GRIN are in brackets]

[Calceolariaceae:]
Calceolaria spp., calceolaria

[Phrymaceae:]
Mimulus ×hybridus, tiger monkeyflower

[Plantaginaceae:]
Antirrhinum spp., snapdragon
Collinsia heterophylla, Chinese-houses
Digitalis spp., foxglove
Linaria spp., linaria
Penstemon barbatus, beardlip penstemon
Penstemon eatonii, firecracker penstemon
Penstemon palmeri, Palmer penstemon
Penstemon penlandii, Penland's beardtongue
Penstemon strictus, Rocky Mtn. penstemon
Penstemon spp., penstemon
Veronica austriaca, Hungarian speedwell
Veronica spicata, spike speedwell

[Linderniaceae:]
Torenia fournieri, blue wishbone-flower

[Scrophulariaceae:]
Nemesia spp., nemesia

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Fleshy endosperm and leaf-like cotyledons.

Shoot system: The hypocotyl elongates carrying the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A primary root; secondary roots or root hairs may develop within the test period.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay (see note 1).

Epicotyl:
- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl:
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.
- watery (see note 3).

Root:
- none.
- weak, missing or stubby primary root (secondary roots will not compensate for a defective primary root).

Seedling:

- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. Seedlings with unshed seed coats may have decayed or damaged cotyledons. The seed coat must be removed for evaluation of the cotyledons.

2. The use of gibberellic acid (GA_3) is recommended for breaking dormancy in certain species (see Table 6A and sections 6.8 m, 6.8 p, and 6.9 m (4) of the AOSA Rules Vol. 1).

3. In certain species (e.g. *Antirrhinum* spp.), watery or glassy seedlings may be the result of lack of light during germination. Watery seedlings are considered abnormal if not caused by test conditions.

SOLANACEAE, NIGHTSHADE FAMILY I – Pepper, tomato and husk tomato

Capsicum spp., vegetable and ornamental pepper
Physalis pubescens, husk tomato
Physalis spp., physalis
Solanum lycopersicum var. *lycopersicum,* tomato

GENERAL DESCRIPTION

Seeding type: Epigeal dicot.

Food reserves: Cotyledons that expand and become thin, leaf-like and photosynthetic; fleshy endosperm.

Shoot system: The hypocotyl elongates carrying the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A long primary root, usually with root hairs. Secondary or adventitious roots usually do not develop within the test period unless the primary root has been damaged.

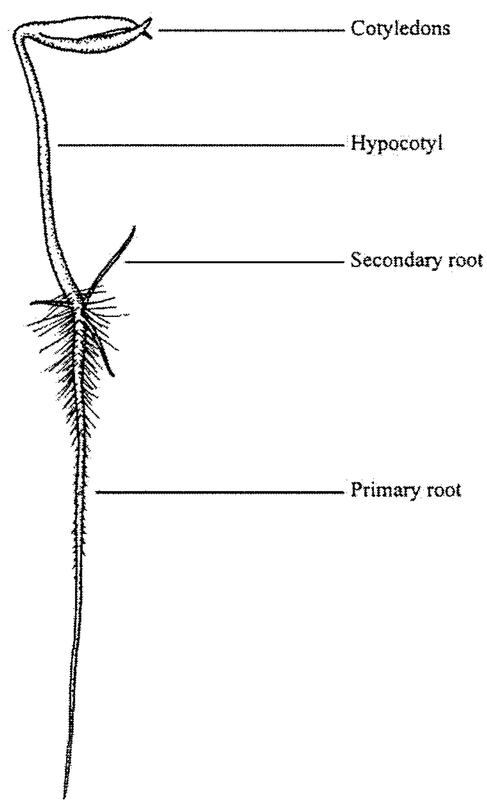


Fig. 1 Pepper.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay (see note 1).

Epicotyl:
- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl:
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.
- watery.

Root:
- none.
- weak, stubby or missing primary root with weak secondary or adventitious roots (see note 2; for seed coat - bound roots in *Capsicum* spp., see note 3).

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. In all members of this group, unshed seed coats must be removed in order to evaluate the cotyledons. In *Capsicum* spp., there can be a problem with seed coats adhering to the cotyledons that often causes mechanical injury to the cotyledons. This can be caused by the inflexible seed coat and less than optimum moisture after radicle emergence. Testing in rolled paper towels can reduce this problem, but see note 3.

2. A normal root system may include a damaged or missing primary root as long as there are at least two strong secondary or adventitious roots present and the hypocotyl is near normal length.

3. In *Capsicum* spp., the primary root may become bound up in the seed coat at the base of the hypocotyl that may prevent the formation of a completely developed primary root or secondary roots or both. The frequency of this bound root condition varies with different test methods. While the analyst should classify most seedlings with a bound primary root to be normal, a test method should be used which is known to avoid the bound primary root condition in pepper. Placing pepper seeds in rolled towels that are slanted at a 45° angle until the first count is made may help to reduce the bound root problem. See Peterson and Harris 2000 in References for further information.

REFERENCES

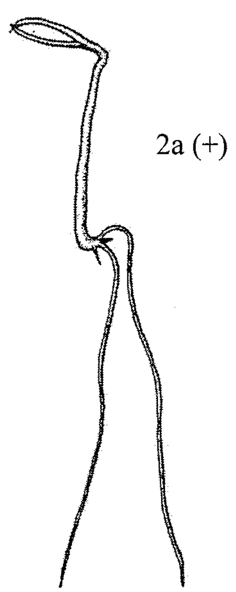
Ertsey, K.J. 1978. The assessment of abnormal root types in *Lycopersicon lycopersicum* and the role of secondary roots in the development of the plants. Seed Sci. & Technol., 6(3):735-747.

Miguel, M.C. 1978. Report of the germination committee working group on evaluation of seedlings with root damage. 1974-1977. Seed Sci. & Technol., 6(1):203-212.

Peterson, P. and E. Harris. April 2000. Seedling Evaluation of Bound Primary Roots in Pepper (*Capsicum* spp.) Solanaceae. California Dept. of Food and Agriculture. (This paper is available from the California State Seed Lab and will be submitted to *Seed Technology*).

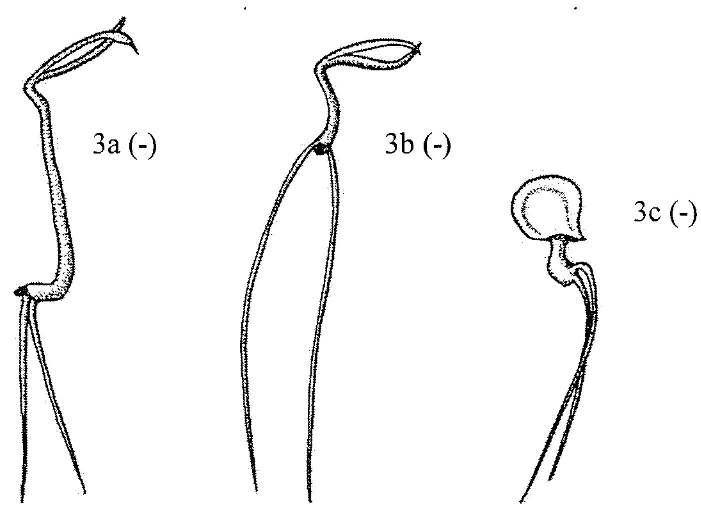
USDA. 1952. Manual for Testing Agricultural and Vegetable Seeds. Agriculture Handbook No. 30, p. 171.

Fig. 2 Root defects (normal).



2a. Primary root damaged, sufficient secondary roots.

Fig. 3 Root and hypocotyl defects (abnormal).

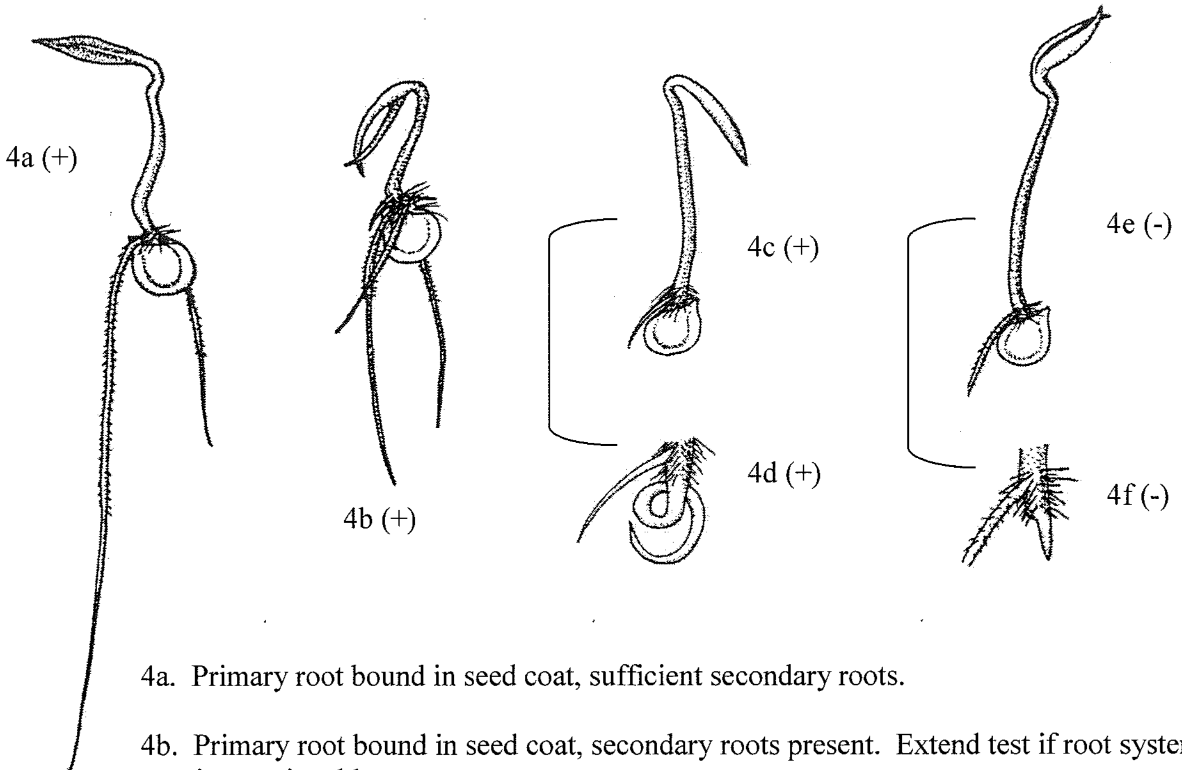


3a. Primary root damaged, insufficient secondary roots.

3b. Hypocotyl short, thickened, with lesion at base.

3c. Hypocotyl short, thickened; primary root damaged; seed coat not shed.

Fig. 4 Bound roots (pepper, substratum T).



4a. Primary root bound in seed coat, sufficient secondary roots.

4b. Primary root bound in seed coat, secondary roots present. Extend test if root system is questionable.

4c. Primary root present, bound in seed coat (see note 3).

4d. Seed coat removed to expose root.

4e. Primary root damage, bound in seed coat; insufficient secondary roots (see note 3).

4f. Seed coat removed to expose root.

SOLANACEAE, NIGHTSHADE FAMILY II – Kinds other than pepper, tomato, and husk tomato

Atropa belladonna, belladonna
Browallia spp., bush violet
Brugmansia arborea, angel's trumpet
Nicotiana alata, flowering tobacco
Nicotiana ×sanderae, nicotiana
Nicotiana tabacum, tobacco
Nierembergia spp., cupflower
Petunia spp., petunia
Salpiglossis sinuata, painted-tongue
Schizanthus spp., butterfly flower
Solanum melongena, eggplant
Solanum spp., nightshade

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons that expand and become thin, leaf-like and photosynthetic. Fleshy endosperm.

Shoot system: The hypocotyl elongates and carries the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A primary root; secondary roots or root hairs may develop within the test period for some species.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:
- missing (may be assumed to be present if the cotyledons are intact).

Hypocotyl:
- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled, or thickened.
- watery (see note 1).

Root:
- weak, stubby or missing primary root regardless of the presence of secondary or adventitious roots (see notes 2 and 3).
- primary root with lesions.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

1. The appearance of glassy-looking hypocotyls may be the result of unfavorable laboratory conditions, such as too much moisture during the germination test.

2. Secondary or adventitious roots may develop within the test period for some species. This would be considered normal as long as the primary root is also present.

3. The primary roots in some of the small-seeded species in this group (e.g. *Petunia*) may appear to be stunted. These seedlings are counted as normal as long as there is sufficient root and/or root hairs to hold the seedlings upright and as long as everything else appears to be normal.

TROPAEOLACEAE, TROPAEOLUM FAMILY

Tropaeolum spp., Nasturtium

GENERAL DESCRIPTION

Seedling type: Hypogeal dicot

Food reserves: Cotyledons that are large and fleshy, and remain enclosed within the seed coat beneath the soil surface.

Shoot system: The shoot system consists of the elongated epicotyl and the terminal bud with developing primary leaves. The hypocotyl does not elongate.

Root system: The root system consists of a primary root and secondary roots.

Fig. 1 **Normal Seedlings**

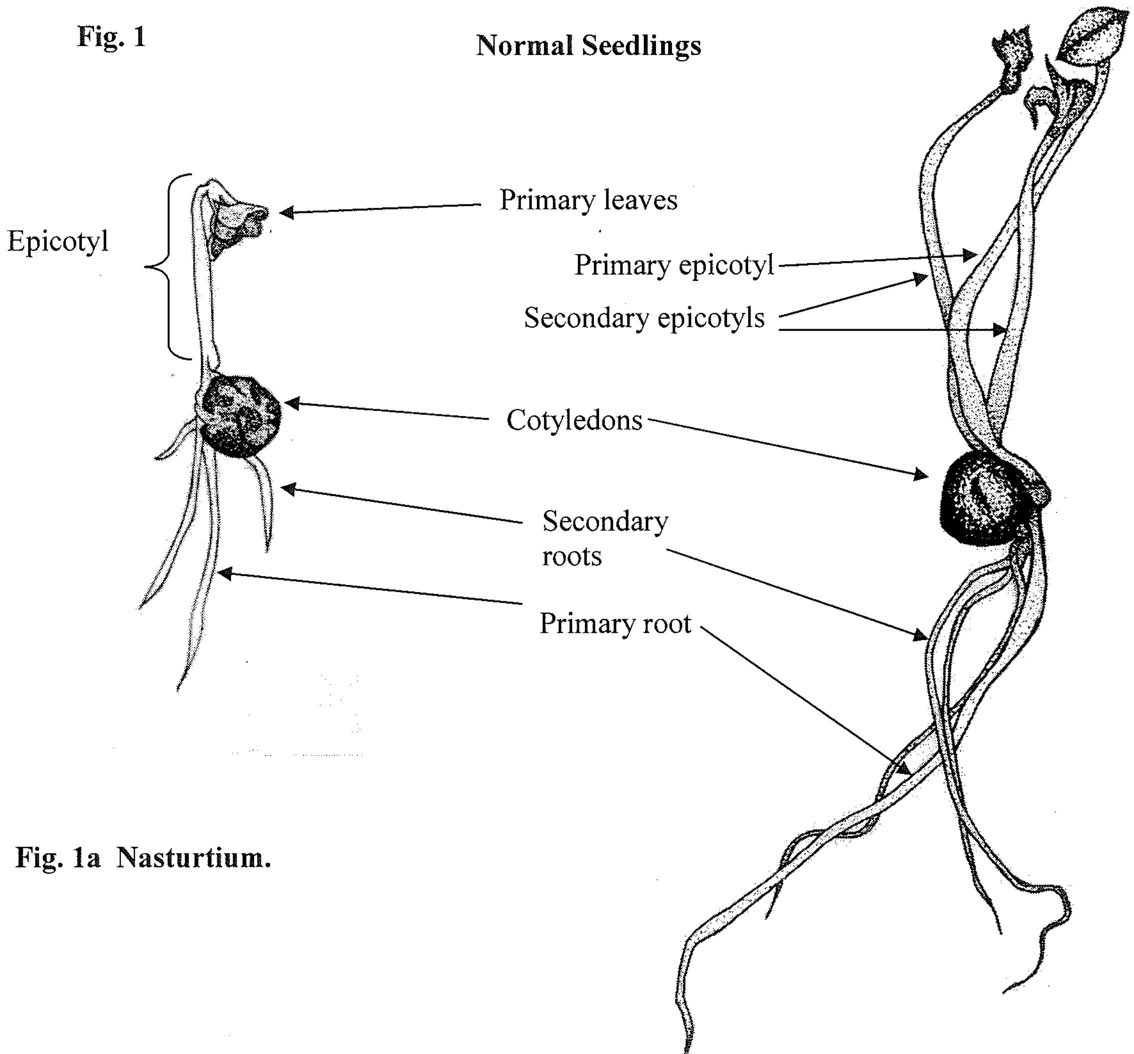


Fig. 1a Nasturtium.

Fig. 1b Nasturtium.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:
- missing.
- less than one primary leaf.
- malformed stem such as markedly shortened, curled, or thickened.
- terminal bud missing, decayed or severely damaged. Secondary epicotyl will not compensate.
- deep, open cracks into the conducting tissue.

Root:
- none.
- weak, stubby or missing primary root with less than two strong secondary roots.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- glassy.
- albino.

NOTES:

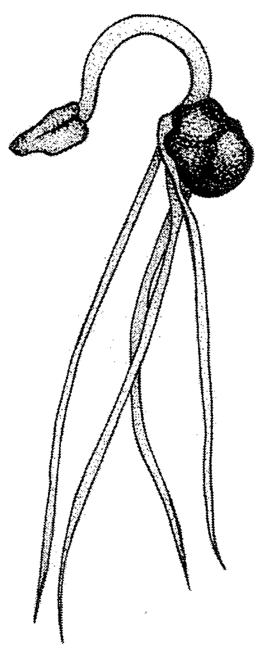


Fig. 1c Normal curling of epicotyl, due to testing conditions in towel.

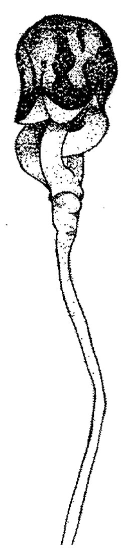
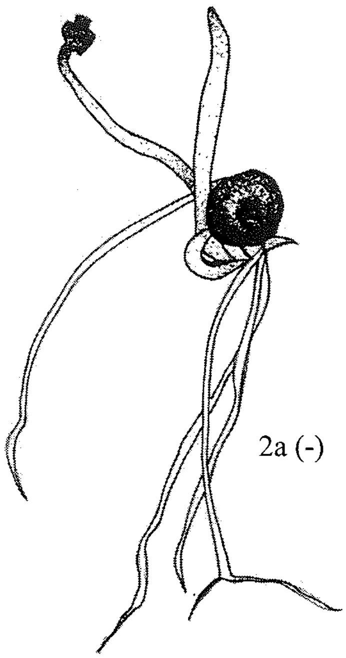
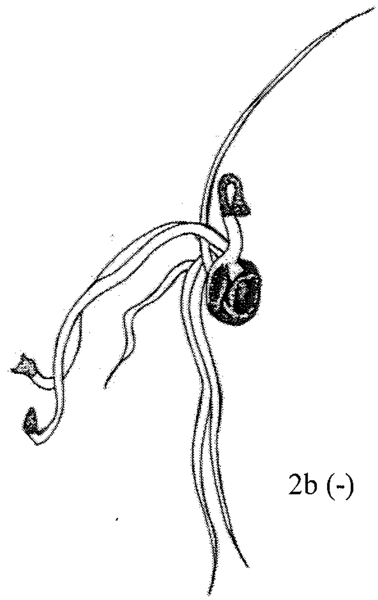
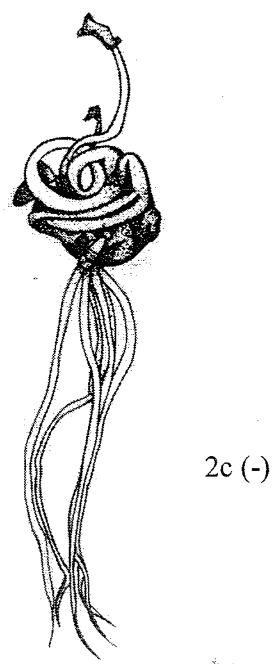


Fig. 1d Slow seedling. Extend 2 days.

Fig. 2 Epicotyl defects.





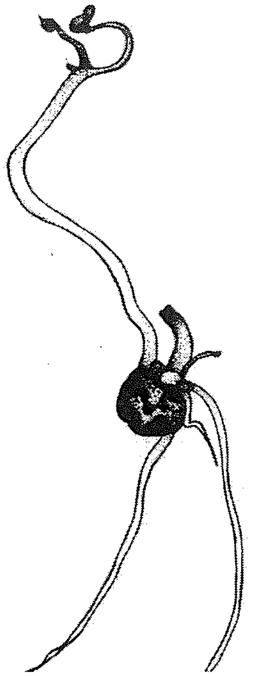


2a. Shortened and thickened epicotyl with missing first true leaf. Secondary epicotyl will not compensate.

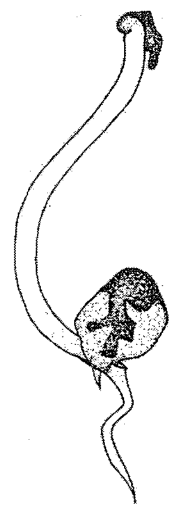
2b. Terminal bud decayed. Secondary epicotyl will not compensate.

2c. Curled epicotyl.

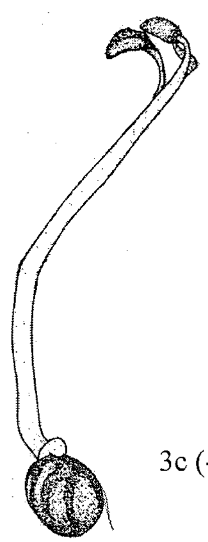
Fig. 3 Root Defects.



3a (+)



3b (-)



3c (-)

3a. Missing primary root with sufficient secondary roots.

3b. Weak primary root with no secondary roots.

3c. Missing primary root and no secondary roots.

VIOLACEAE, VIOLET FAMILY

Viola cornuta, viola
Viola tricolor, pansy

GENERAL DESCRIPTION

Seedling type: Epigeal dicot.

Food reserves: Cotyledons that expand and become thin, leaf-like and photosynthetic; endosperm.

Shoot system: The hypocotyl elongates and carries the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A primary root with root hairs usually developing within the test period.

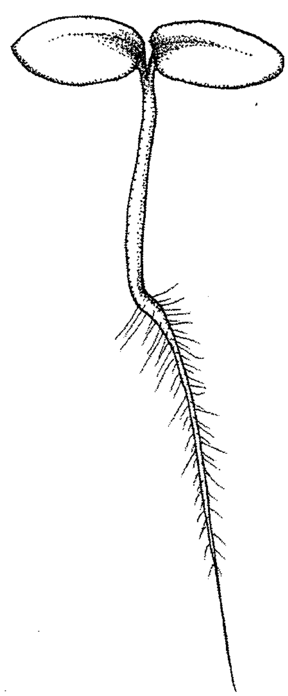


Fig. 1 Viola.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:

- less than half of the original cotyledon tissue remaining attached (see note 1).
- less than half of the original cotyledon tissue free of necrosis or decay (see note 2).

Epicotyl:

- missing (may be assumed to be present if cotyledons are intact).
- decayed at growing point.

Hypocotyl:

- deep open cracks extending into the conducting tissue.
- malformed, such as markedly shortened, curled or thickened.
- watery.

Root:

- weak, stubby or missing primary root (secondary roots will not compensate for a defective primary root; see note 3).

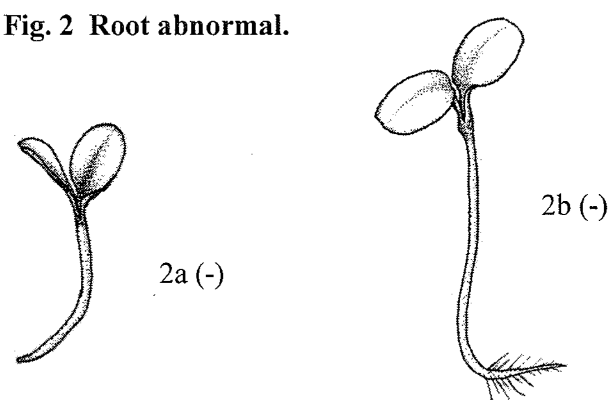
Seedling:

- one or more essential structures impaired as a result of decay from primary infection.
- albino.

NOTES

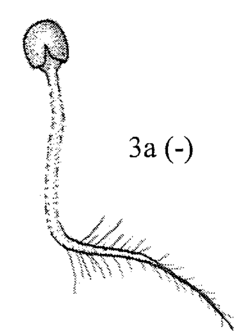
1. Seedlings in this group may produce three cotyledons instead of two. Such a seedling should be considered normal as long as the seedling is otherwise normal.
2. Seedlings with unshed seed coats may have decayed cotyledons. The seed coat must be removed for evaluation. If the seed coat cannot be removed, the seedling is classified as abnormal.
3. Certain cultivars of pansy may have a characteristically short primary root. This should be considered normal as long as the proportions between the root and the hypocotyl are balanced.

Fig. 2 Root abnormal.



2a. Missing primary root.
2b. Stubby primary root.

Fig. 3 Hypocotyl abnormal.



3a. Hypocotyl watery, seed coat not shed.

MISCELLANEOUS AGRICULTURAL AND HORTICULTURAL

Boraginaceae, borage family – borage
Cannabinaceae, hemp family – hemp
Dichondraceae [Convolvulaceae], dichondra family – dichondra
Lamiaceae, mint family – balm, catnip, rosemary, sage, summer savory, sweet basil, sweet marjoram, thyme
Pedaliaceae, benne family – sesame
Rosaceae, rose family – little burnet
Valerianaceae [Caprifoliaceae], valerian family – cornsalad

GENERAL DESCRIPTION

Seedlings are considered normal if they possess those essential structures that are indicative of its ability to produce a plant under favorable conditions.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:
- missing (may be assumed to be present if the cotyledons are intact).

Hypocotyl:
- malformed, such as markedly shortened, curled or thickened.
- deep open cracks extending into the conducting tissue.
- watery.

Root:
- none.
- missing or stubby primary root with weak secondary or adventitious roots.

TREES AND SHRUBS I - Gymnosperms

Cupressaceae: *Calocedrus decurrens*
Chamaecyparis spp.
Platycladus orientalis
Sequoia sempervirens [also placed in Taxodiaceae]
Sequoiadendron giganteum [also placed in Taxodiaceae]
Thuja spp.

Pinaceae: *Abies* spp.
Cedrus spp.
Larix spp.
Picea spp.
Pinus spp.
Pseudotsuga menziesii
Tsuga spp.

GENERAL DESCRIPTION

Germination type: Epigeal.

Food reserves: Gametophyte tissue that is adsorbed through the cotyledons. The remnant falls off with the seed coat after hypocotyl elongation and soil emergence.

Shoot system: The hypocotyl elongates carrying the cotyledons above the soil surface; the epicotyl usually does not show any development within the test period.

Root system: A long primary root.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- emerging before the radicle.
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:
- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl:
- short, thickened - dwarf.
- grainy in appearance.
- carrying a collar of gametophyte tissue.
- for *Pinus palustris*, see note 1.

Root:

- weak, stubby or missing primary root (secondary roots will not compensate for a defective primary root).
- trapped in the seed coat.
- growing upward - negative geotropism.

Seedling:

- one or more essential structures impaired as a result of primary infection.
- fused embryos (twin embryos are normal provided one of the embryos is otherwise normal).
- weak or broken.
- watery - translucent in appearance.
- albino.

NOTES

1. In a typical seedling of *Pinus palustris*, the hypocotyl is 5 mm or less in length. When planting in soil, the seed must be left exposed, otherwise the hypocotyl will not elongate sufficiently to raise the cotyledons above the soil and the accuracy of the test will be impaired.

TREES AND SHRUBS II - Angiosperms with hypogeal germination

Fagaceae - *Quercus* spp.
Hippocastanaceae [Sapindaceae] - *Aesculus pavia*
Juglandaceae - *Carya* spp.

GENERAL DESCRIPTION

Germination type: Hypogeal.

Food reserves: Cotyledons that are large and fleshy, and remain enclosed within the seed coat beneath the soil surface. They are usually not photosynthetic.

Shoot system: The epicotyl elongates and carries the terminal bud and primary leaves above the soil surface. The stem bears one or more scale leaves and, prior to emergence, is arched near the apex, causing the terminal bud to be pulled through the soil; after emergence, the stem straightens. For practical purposes the hypocotyl is not discernible and is not an evaluation factor. There are buds in the axils of each cotyledon and scale leaf, but these usually remain dormant unless the terminal bud is seriously damaged.

Root system: A long primary root with secondary roots.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:
- missing.
- less than one primary leaf.
- malformed stem, such as markedly shortened, curled, or thickened.
- deep, open cracks extending into the conducting tissue.
- terminal bud missing or damaged (seedling is classified as abnormal even if axillary shoots have developed).

Root:
- none.
- weak, stubby or missing primary root with weak secondary roots.
- growing upward - negative geotropism.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- fused embryos.
- weak or broken.
- watery.
- albino.

TREES AND SHRUBS III - Angiosperms with epigeal germination

Aceraceae [Sapindaceae] - *Acer* spp.
Asteraceae - *Artemisia* spp. (for *A. ludoviciana* – see Asteraceae II)
Betulaceae - *Betula* spp.
Bignoniaceae - *Catalpa* spp.
Casuarinaceae - *Casuarina* spp.
Chenopodiaceae - *Atriplex canescens*, *Krascheninnikovia lanata*
Cornaceae - *Cornus* spp.
Ephedraceae - *Ephedra viridis*
Ericaceae - *Rhododendron* spp.
Fabaceae - *Gleditsia triacanthos*, *Robinia pseudoacacia*
Hamamelidaceae [Altingiaceae] - *Liquidambar styraciflua*
Magnoliaceae - *Liriodendron tulipifera*, *Magnolia grandiflora*
Myrtaceae - *Eucalyptus* spp.
Nyssaceae [Cornaceae] - *Nyssa* spp.
Oleaceae - *Fraxinus* spp., *Syringa vulgaris*
Platanaceae - *Platanus occidentalis*
Proteaceae - *Grevillea robusta*
Rosaceae - *Crataegus mollis*, *Purshia* spp., *Rosa multiflora*
Salicaceae - *Populus* spp.
Simaroubaceae - *Ailanthus altissima*
Ulmaceae - *Ulmus* spp.
Vitaceae - *Vitis vulpina*

GENERAL DESCRIPTION

Germination type: Epigeal.

Food reserves: Cotyledons.

Shoot system: The hypocotyl elongates carrying the cotyledons above the soil surface. The epicotyl usually does not show any development within the test period.

Root system: A primary root; secondary roots may develop within the test period.

ABNORMAL SEEDLING DESCRIPTION

Cotyledons:

- emerging before the radicle.
- less than half of the original cotyledon tissue remaining attached.
- less than half of the original cotyledon tissue free of necrosis or decay.

Epicotyl:

- missing (may be assumed to be present if cotyledons are intact).

Hypocotyl:
- malformed, such as markedly shortened, curled or thickened.
- deep, open cracks extending into the conducting tissue.

Root:
- none.
- missing or stubby primary root with weak secondary or adventitious roots.
- growing upward - negative geotropism.

Seedling:
- one or more essential structures impaired as a result of decay from primary infection.
- albino.
- watery - translucent in appearance.
- fused embryos.
- weak or broken.

PART III. GLOSSARY

Abnormal seedling. A seedling that does not have all the essential structures or is damaged, deformed or decayed to such an extent that normal development is prevented (see normal seedling).

Achene. A dry, hard, one-chambered, one-seeded indehiscent fruit, as in buckwheat, sunflower and spinach. The fruit wall is not united with the seed coat.

Adventitious root. A root arising from any structure other than a root (e.g. a stem-borne root).

Albino. A seedling in which all tissues are white due to the absence of pigments.

Caryopsis. The single-seeded fruit or grain of the grass family (Poaceae); the fruit wall (pericarp) is united with the seed coat (testa).

Coleoptile. The sheath enclosing the terminal bud of the embryo and the developing leaves of the young seedling of the grass family (Poaceae).

Coleorhiza. The sheath enclosing the radicle of the grass embryo.

Conducting tissues. Tissues that transport water and dissolved minerals from the root to the other plant structures, and foods from where they are manufactured (e.g. leaves) to where they are needed for growth or storage.

Cotyledon. The modified storage leaf or pair of leaves of an embryo and seedling (see primary leaf).

Dead seeds. Seeds that at the end of the test period are neither hard nor dormant nor have produced any part of a seedling.

Decay. Break-down of organic tissue, usually associated with the presence of micro-organisms.

Dicotyledons. A group of plants so classified because the embryo usually has two cotyledons (see monocotyledons).

Diseased. Showing symptoms of the presence and activity of pathological or detrimental micro-organisms.

Dormant seed. Viable seeds, other than hard seeds that fail to germinate when provided the specified germination conditions for the kind of seed in question.

Embryo. A rudimentary plant contained in a seed, usually consisting of a more or less differentiated axis and attached cotyledon(s).

Endosperm. Nutritive tissue originating from fertilization and retained at maturity in some seeds as storage for food reserves.

Epicotyl. The part of the seedling above the cotyledons, consisting of the epicotyl stem, the developing leaves and the terminal bud.

Epigeal germination. A type of germination in which cotyledons are carried above soil level by the elongating hypocotyl (see hypogeal germination).

Female gametophyte. The nutritive tissue in seeds of gymnosperms. It develops without fertilization, therefore it is sometimes called primary endosperm.

Geotropism. Plant growth response to gravity.

Hard seed. Seed that remain hard at the end of the prescribed test period because they have not absorbed water due to an impermeable seed coat.

Hypocotyl. The part of the seedling above the primary root and below the cotyledons.

Hypogeal germination. A type of germination in which the cotyledon(s) or comparable structure (e.g. scutellum) remain in the soil (see epigeal germination).

Imbibition. The uptake of water by the seed from the germination substrate.

Impaired. Unable to function normally, in reference to damaged seedling structures.

Infection. Entrance and spread of disease organisms in living material (e.g. seedling structures) often causing disease symptoms and decay.

> **Primary infection:** Disease organism present and active in the seed and/or seedling itself.
>
> **Secondary infection:** Disease organism spreading from other seeds or seedlings or adhering structures (such as the cluster of *Beta*).

Meristem. Plant tissues composed of undifferentiated cells that initiate cell division.

Mesocotyl. In some highly specialized monocotyledons (e.g. certain Poaceae) the part of the seedling between the scutellar node and the coleoptile.

Monocotyledons. A group of plants so classified because the embryo usually has one cotyledon (see dicotyledons).

Necrosis. Dead or deteriorating seedling tissue that may be caused by injury, disease or physiological breakdown.

Normal seedling. A seedling with all essential structures present and capable of developing into a plant under favorable conditions; certain defects may be present if they are judged to be not so severe as to impede further development of the plant (see abnormal seedling).

Nucellus. Tissue of the inner part of an ovule in which the embryo sac develops; it may persist as nutritive tissue in some seeds (see perisperm).

Pericarp. Fruit wall; derived from the ovary wall.

Perisperm. Nutritive tissue occurring within certain seeds (e.g. *Beta*), derived from the nucellus; similar in function to endosperm.

Petiole. The stalk of a leaf.

Phytotoxic. Poisonous to plants.

Primary infection. See infection.

Primary leaf. The first leaf or leaves above the cotyledons.

Primary root. Main root of the seedling, developing from the radicle of the embryo.

Radicle. The rudimentary root of the embryo, developing into the primary root after emergence from the seed.

Root hair. Fine tubular growth from an epidermal cell of a root.

Scale leaf. A reduced leaf, usually appressed to the stem (e.g. in *Asparagus*, *Pisum*).

Scutellum. A shield shaped cotyledonary structure in the embryo of the grasses (Poaceae) that absorbs nutrients from the endosperm and provides energy for germination.

Secondary infection. See infection.

Secondary root. Any root other than primary, seminal or adventitious roots.

Seed unit. The structure usually regarded as a seed in planting practices and in commercial channels, consisting of a true seed with or without accessory structures, as defined in Section 2.6 of the AOSA Rules. See also true seed.

Seedling. A young plant developing from the embryo of a seed.

Seminal roots. Roots arising from the scutellar node in Poaceae.

Shoot. A collective term including all structures above the root in epigeal species and above the cotyledonary node in hypogeal species. In the Poaceae, all structures above the scutellar node are included, i.e. the mesocotyl, coleoptile and leaves.

Spindly. Disproportionately thin relative to length; thread-like in appearance.

Stubby root. Blunt, broken off or dwarfed.

Terminal bud. The apical meristem of the epicotyl enveloped by several more or less differentiated leaves.

Testa. Seed coat. The covering structure of a true seed; derived from the integument(s).

True seed. A mature fertilized ovule consisting of an embryo, with or without an external food reserve (e.g. endosperm) enclosed by the testa.

Vascular tissues. See conducting tissues.

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