A Detached Leaf Technique for Studying Race-specific Resistance to

*Cladosporium caryigenum* in Pecan

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Abstract. A detached leaf screening technique was developed for studying specific interactions between pecan (*Carya illinoinensis* (Wangenh.) C. Koch) cultivars and isolates of the pecan scab fungus *Cladosporium caryigenum*. Monoconidial isolates were obtained from leaf scab lesions on ‘Wichita’, ‘Desirable’, ‘Cape Fear’, and ‘Elliot’. Each isolate was then inoculated onto detached leaves of each of the four cultivars and fungal growth was observed under the microscope after eight days. ‘Wichita’, ‘Desirable’, and ‘Cape Fear’ isolates produced subcuticular hyphae at a much higher frequency when inoculated back onto the cultivar from which they were isolated in comparison to the other cultivars. The results obtained indicate that pecan scab is composed of multiple races with a high degree of specificity for host cultivars. A rapid whole-leaf staining system is presented which appears to have wide applicability to assessing fungal growth in leaves.
I)  

Pecans \([Carya illinoensis \text{ (Wangenh.) C. Koch)}\] are attacked by a wide range of pathogen and insect pests which cause substantial crop losses. In the humid growing conditions of the southeastern United States, the most economically damaging pest is the fungus \(Cladosporium\) \textit{caryigenum}\ which causes pecan scab. Scab infection reduces both yield and quality of nuts, and if uncontrolled results in total crop loss (Sanderlin, 1994).

b)  

Materials and Methods

\textit{Isolate preparation}. Isolates were obtained from each of the four cultivars; ‘Wichita’ (Wi-Tif-2), ‘Desirable’ (De-Tif-3), ‘Cape Fear’ (Cf-Au-2), and ‘Elliot’ (El-Au-2). Conidia from individual lesions were suspended in a drop of water and spread across a petri dish containing 1\% water agar. Plates were incubated at room temperature for 24 h and then single germinated conidia were transferred to potato dextrose agar containing the antibiotics streptomycin, chloramphenicol, and tetracycline at 50 g·L⁻¹. Plates were placed in a growth chamber set at 24 °C with a 12-h photoperiod provided by fluorescent lights (115 \(\mu\text{mol·m}^{-2}\cdot\text{s}^{-1}\)) for 2 weeks. After 1 to 2 weeks growth, conidia were harvested and the concentration adjusted to \(1 \times 10^6\) conidia/mL of water with a hemacytometer.
Results

At 4 d PI conidia had germinated and formed germ tubes and appressoria on leaves of all four cultivars. Inoculating Wi-Tif-2 conidia on to ‘Wichita’ leaves showed over 40% (Fig. 1A) of the conidia penetrating the cuticle underneath the appressorium and producing clearly visible subcuticular hyphae between the cuticle and epidermal cell layer. Field inoculations validated the results from the detached leaf study in that the greatest infection frequency resulted from inoculation of a cultivar with an isolate obtained from that cultivar (Table 1). Isolate Wi-Tif-2 produced a large number of lesions on ‘Wichita’ leaves but not on the other three cultivars.

Discussion

A detached leaf screening system is highly advantageous in this plant-pathogen system because the size of the host plant makes greenhouse and growth chamber studies difficult. Previous studies made use of a chloral hydrate-acid fuchsin staining system that requires several days to complete (Latham and Rushing, 1988; Yates et al., 1996). In summary, this research indicates that pecan cultivars display vertical or race-specific resistance to pecan scab. Results to date indicate that the scab pathogen consists of a large number of races, each well-adapted to its host cultivar. Therefore, a resistance breeding program should challenge potential new cultivars with a wide range of scab isolates in order to lower the likelihood of escapes being misclassified as resistant.


Table 1. Number of scab lesions per square centimeter produced from field inoculations of four pecan cultivars with two pecan scab isolates.

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<tr>
<td></td>
<td></td>
<td></td>
<td>No. scab lesions/cm²</td>
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<td>1.13 b</td>
<td>0.00 a</td>
<td>--- x</td>
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</tbody>
</table>

*Number of days between inoculation and sample counts.

*Any two means within a row not followed by the same letter are significantly different at $P \leq 0.01$.

*xInoculation test not performed.

Fig. 1. Chronology of pathogen development on resistant and susceptible cultivars. Leaves of the four cultivars were inoculated with *Cladosporium caryigenum* isolated from ‘Wichita’. Leaves were examined microscopically at (A) 4, (B) 8, and (C) 14 d postinoculation. The percent of the germinated conidia producing subcuticular hyphae, reproductive initials, and sporulation were determined. Mean totals with a common letter are not different ($P \leq 0.05$) by ANOVA on ranks test.
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**Abbreviations for Literature Cited**

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<td>Yearbook</td>
</tr>
</tbody>
</table>
J) Tables

Tables should document but not duplicate data already given in the text. **Make a separate table for each data set; that is, do not design a table that contains another table.**

Start each table (with all parts double-spaced) on a separate page and number each table with Arabic numerals (e.g., Table 1, Table 2, etc.). Place tables after Literature Cited. The title, column and row headings, and footnotes of each table should be self-explanatory. Capitalize only the first letter of the first word of each column and row heading.

To identify tabular footnotes, use lowercase letters starting from the end of the alphabet (sequence z, y, x…). If letters or symbols are used to indicate statistical significance at different levels, use (with explanatory footnotes) either lowercase letters from the beginning of the alphabet (a, b, c…) or a single asterisk (*) for $P \leq 0.05$, either uppercase letters from the beginning of the alphabet (A, B, C…) or a double asterisk (**) for $P \leq 0.01$, and a triple asterisk (***) for $P \leq 0.001$.

As an example, the following footnote adequately identifies letters in mean separation tests:

Mean separation (in rows, columns, etc.) by Duncan’s multiple range test at $P \leq 0.05$ (lowercase letters) or 0.01 (uppercase letters).

The following footnote is suitable when symbols are used to designate significance:

Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

K) Figures

Illustrations are often the best means for presenting scientific data, revealing trends, or recording natural appearance. Data presented in tables should not be duplicated in figures.

Identify all graphs, line drawings, and photographs with consecutive Arabic numerals (e.g., Fig. 1, 2, or 3).

Number the figures in the sequence in which they are cited in the text. All figures must be cited.

**Cite figures in text in the following manner:**

...as shown in Fig. 1

...as shown in Figs. 1–3

...as shown in Fig. 1A (but Fig. 1A and B, or Fig. 1A–C, **NOT** Figs. 1A and B)

Information in captions should be clear and concise and understood independently from the text (all acronyms and
abbreviations should be spelled out as in the text).

Legends and equations may be in the figure. Symbols used in graphs and charts should be keyed. If symbols are necessary for reference in the text, then choose standard symbols, such as the triangle, box, or circle. Complex symbols do not translate from disks and cannot be replicated easily.

Black-and-white photographs must be clear, with sharp focus and good density.

Color reproduction is available at additional cost.

For graphs or photographs that are grouped as one composite figure, place letters on each frame to correspond to the caption. Assign letters from left to right, then top to bottom. Be sure that letters are of uniform height and density and that they will be legible when reproduced (e.g., if the background in a photograph is dark, do not use black letters).

For electronic graphics, you may embed them in the text file. If submitting them as separate files, TIFF, EPS, JPG, or PDF formats are preferred.

Lettering should be of a consistent size and style. Size and boldness of lettering on figures should be gauged for legibility in the final production size; letters or numerals 3 mm high or higher generally are satisfactory.

Abbreviations and symbols used in figures must conform to the style used in the text. Acronyms used in the figure should be spelled out in the caption.

Use of perspective or three-dimensional graphics is discouraged in bar and line graphs.

Use single quotation marks for cultivar names within captions but not when they are placed on the axes of a graph. Make all symbols and scatter-plot dots large enough to reproduce clearly without blurring.

Figures with similar types of data and the same horizontal scales should be stacked, when feasible.

Do not italicize or bold the identification “Fig.” in the caption.
The manuscript must conform to current standards of English usage and style. ASHS, in general, conforms to the 14th edition of *The Chicago Manual of Style*.

Clarity of writing is necessary. Avoid wording in “notebook style” (i.e., using incomplete sentences and omitting prepositions, verbs, and articles). First- and third-person pronouns are accepted and preferred for clarity. Use the active voice whenever possible.

**WEAK**: The plants were watered by the experimenters once a week.

**STRONG**: We watered the plants weekly.

All papers must use American English spellings. Because ASHS publications have a broad international readership, avoid slang, jargon, local vernacular, and coined terms.

When discussing a horticultural crop as a class, the singular form may be used (e.g., “this trait is common in apple.”).

Do not use a comparative without stating the standard for comparison. For example, “treatment A produced larger apples” is obscure—larger than what? While some comparisons are inferred by context or a previous statement, many are vague. Restructuring the sentence may be preferred.

**CHEMICAL TERMINOLOGY**

**Chemical Nomenclature and Formulas**

Whenever possible, simplify chemical formulas and names for readability and typographical considerations. Use the common name or abbreviation of a chemical—not the chemical name—in the title, the additional index words, and the abstract. At the end of the abstract, list each chemical name that was used in the abstract followed by its common name or abbreviation in parentheses. If a chemical is first mentioned in the text, give the full chemical name in parentheses following the common name or abbreviation; thereafter, the common name or abbreviation may be used. Give the specific analog to abbreviation in subscript (e.g., GA$_3$). Greek characters may be used in full formulas; do not substitute Roman-letter equivalents for Greek symbols.

Indicate chemical elements and common compounds by their chemical symbols. Spell out the chemical name only if confusion may result with other symbols or with words or numerals: helium (He), oxygen (O), iodine (I), and arsenic (As).
Do not begin sentences with a chemical symbol (e.g., “P is necessary for growth.” is not acceptable). Give formulas for molecules of elemental gases (e.g., H\textsubscript{2}O). Indicate isotopes different from the normal with superscript numbers preceding the element symbol [e.g., \textsuperscript{14}C(2-chloroethyl)phosphonic acid].

General mention of a salt or its concentration in solution may be given as the simplest formula (e.g., Na\textsubscript{2}SO\textsubscript{4}). Give full molecular formulas for hydrated salts [e.g., BaCl\textsubscript{2}H\textsubscript{2}O (use the raised period, with no space before and after the period for water of hydration)]. Indicate ion charges with superscripts (e.g., H\textsuperscript{+}, Cl\textsuperscript{-}); use Ca\textsuperscript{2+}, not Ca\textsuperscript{++} or Ca\textsuperscript{+2}.

All experimental materials must be characterized as to chemical content. Use care in reporting information on proprietary materials.

**Fertilizer Analysis**

Report amounts and proportions of nutrients in elemental terms, not as oxides (e.g., K, not K\textsubscript{2}O, or P, not P\textsubscript{2}O\textsubscript{5}). In general, nitrogen–phosphorus–potassium fertilizer reference may be abbreviated N–P–K, with en-dashes. Give the source of the nutrient (e.g., sulfate, nitrate, etc.). Where proportions are given, list the amounts up to one decimal point without spaces between the numerals and the element, with en-dashes separating each [e.g., 10N–4.3P–8.3K, not 10-4.3-8.3 (N-P-K) or 10N–4P–8K]. When sulfur (or any other element) analysis is important (such as with a sulfur-coated urea), report S (or the other element) (e.g., 44N–0P–0K–13S. For the two commonly used slow-release fertilizers (Osmocote 14–14–14 and Osmocote 18–6–12), use 14N–4.2P–11.6K and 18N–2.6P–9.9K, respectively. To describe the rate of incorporation (e.g., 8, 16, and 32 g/pot), writing “8 g (Osmocote 144.211.6)/pot” each time the rate is mentioned or discussed is not necessary; once defined, only the concentration needs to be specified. Use the following formula to convert to the proper format: \( P = 0.437 \times P_2O_5 \) and \( K = 0.830 \times K_2O \), so a fertilizer with the analysis 10–10–10 would be reported at 10N–4.4P–8.3K.

**Pesticides and Plant Growth Regulators**

Common or generic names and abbreviations of pesticides should conform to those approved by the American National Standards Institute Committee K62 on Common Names for Pest Control Chemicals.

**Trade or Brand Names**

Trade or brand names are not permanent; try to refer to the generic form of what you are using (e.g., “We used a tissue to wipe the thermometer.” instead of “We used a Kleenex to wipe the thermometer.”). If you must use brand names,
avoid using them without clarification. In general, refer to trade or brand names only parenthetically with the active ingredient, chemical formula, purity, and diluent or solvent stated clearly in the text and emphasized in preference to the commercial product; also, include the name, city, and state/country of the company that produces the product. Capitalize the first letter of trade or brand names. Avoid use of trade names in titles. If using trade names is unavoidable, include a footnote that disclaims endorsement of similar products of like properties (this is mandatory in some agencies and institutions).

### Nomenclature Use in ASHS Publications

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<th>Text</th>
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<td>Ambiguous common name</td>
<td>Well-known crops</td>
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<td>Yes</td>
</tr>
<tr>
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<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
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<th>Text</th>
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<tbody>
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<td>Yes</td>
</tr>
<tr>
<td>Chemical name</td>
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<td>No</td>
<td>In parentheses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>after common name</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and at end of abstract</td>
</tr>
<tr>
<td>Trade or brand name</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

### DATES

Spell out the names of the days (Sunday through Saturday) in all cases.

Use Arabic numerals for all calendar dates. Abbreviate all months (except May, June, and July) when they are used with a number (e.g., year or date), but spell out the name of the month when it is used alone or at the beginning of a sentence. Abbreviations for months: Jan., Feb., Mar., Apr., Aug., Sept., Oct., Nov., and Dec.

When indicating a specific date, give day (one or two digits), month (abbreviated),
and year (four digits), if necessary, in that order (e.g., 2 Sept. 1983 or 13 July). When indicating a specific month, do not insert a comma between the month and the year (e.g., Oct. 1926). Do not use Arabic numerals for months; “4/3/83” could indicate 3 Apr. 1983 in the United States, but 4 Mar. 1983 in other parts of the world.

When referring to a specific season given with the year, capitalize the first letter (e.g., “Spring 1941”), but “the plants were harvested in summer.”

When referring to a span of 12 months (such as a fiscal year) that includes parts of 2 years or to a continuous period of more than 12 months that includes parts of 2 or more years, use the abbreviated notation (e.g., “1907–08” or “1939–43”). When referring to a span of years that includes change-of-century years, use the full notation (e.g., “1994–2002”).

When referring to a group of continuous years, add the plural “s” without an apostrophe (e.g., “1890s”).

Julian Day is not an acceptable measure of time from the end of the last year. Julian Day = number of days elapsed since 1 Jan. 4713 BCE.

**DORMANCY TERMINOLOGY**

Dormancy is a temporary suspension of visible growth of any plant structure containing a meristem. Ecodormancy includes all cases of dormancy due to unsuitable environmental factors (e.g., temperature extremes and nutrient deficiencies). Endodormancy is used when the dormancy is regulated by physiological factors inside the structure (e.g., chilling responses and photoperiodic responses). Paradormancy is regulated by physiological factors outside the affected structure (e.g., apical dominance and photoperiodic responses).

**EQUATIONS**

When a short equation is used in the text, use parentheses and slant lines to simplify the equation. Simplify complex formulas or equations for legibility or present them as line art and include them with the figures.

Leave space before and after arithmetic symbols. If an equation needs to be divided in the text or a table heading, split it after the arithmetic symbol. Leave line spaces above and below equations in the text and center equations.

Do not number all displayed equations, unless the equation is complex or is referred to elsewhere in discussion. If numbering is necessary, use Arabic numerals placed in brackets (not in parentheses) to the far right of the equation or at the right margin. Set connecting words between equations on lines by themselves, flush against the left margin. When superscript and subscript are combined, indicate which symbol comes first. Refer to an equation in the text as “Eq. [3]” or “Eq. [10].”
FOREIGN NAMES AND WORDS

Names

In general, alphabetize using the particle, not the family, name.

Dutch or Belgian
When alphabetizing, the particle that precedes the family name remains lowercase, e.g., J. van Zanten becomes van Zanten, J. Some American authors of Belgian or Dutch extraction, however, capitalize the particle, e.g., De Hertogh, A.A.

Chinese
The family name precedes the given name (usually hyphenated) when written in Chinese (e.g., Chiang Ching-kuo, when alphabetized, would be Chiang, C.). In American and British journals, however, a Chinese name usually is Anglicized and transposed; e.g., Ching-kuo Chiang.

Egyptian
Arabic names without prefixes or variants place the family name after the given name. Shawki A. Moustafa, therefore, would be cited as Moustafa, S.A. When the particle “el” alone or a prefix or its variant (el, ibn, abdel, abdoul, abu, abou, or aboul) precedes a name, it is hyphenated to the word it precedes in the citation; e.g., Mahoud el Barkooki is cited as el-Barkooki, M. The particle or prefix remains lowercase.

French
The definitive articles (le, la, or les) alone or combined with prepositions (de, du, or des) precede the name in the citation and remain either capitalized or lowercase as they were in the original (e.g., Charles de Gaulle becomes de Gaulle, C., and Maurice LeBeau becomes LeBeau, M.)

German
Names containing articles or their abbreviations precede the family name in a citation and remain lowercase (e.g., Klaus von Krupp becomes von Krupp, K.)

Indian
Modern Indian names place the given name before the family name. If the family name is preceded by Sen or Das, it should remain capitalized and lead the citation (e.g., Natoobhai D. Sen Dhur becomes Sen Dhur, N.D.)

Indonesian
Family names are written last. Some Indonesians, however, have only one name (e.g., Soetono).
**JAPANESE OR KOREAN**

The family name always comes first when written in Japanese or Korean. Western form usually places the given name first (e.g., Yashiro Kosaka is cited as Kosaka, Y.)

**PORTUGUESE**

Citations should carry the particle (do, da, das, dos) in lowercase before the family name (e.g., Alberto Alvares do Santos becomes do Santos, A.A.)

**SPANISH**

Some Spanish names and names of Spanish origin include the maternal after the paternal family name. In the transposed name, the paternal name precedes the maternal name (e.g., Jose Manuel Hernandez Gonzales becomes Hernandez G., J.M., or Carlos Perez y Martinez becomes Perez y Martinez, C.). Note that the maternal name is not separated from the paternal name by a comma in the citation.

**VIETNAMESE**

The family name precedes the given name, but the first name, which is the last element, must be transposed with the middle name (e.g., Ngo Van Hai becomes Ngo, H.V.)

**Words**

Whenever Latin or foreign words or phrases are used, they should be italicized if they have not been naturalized in English, but their abbreviations are not italicized (e.g., *id est*, *nomen novam*, *pro bono publico*, and *raison d’etat* but “i.e.” and “nom.nov.”). Terms that have become part of modern English—such as “media,” “data,” and “bureau” or “in vitro,” “in vivo,” and “in situ”—are not italicized. Pretentious use of foreign phrases is discouraged if a sound English equivalent is available.

Use American, rather than British, spelling (e.g., “color,” not “colour”; “center,” not “centre”; “program,” not “programme”; “rationalize,” not “rationalise”; and “gasoline,” not “petrol.” However, retain the original spelling in quotations and Literature Cited.

Capitalize the names of foreign places when they occur as part of a proper name. In languages where nouns or proper adjectives are always capitalized, retain this style in the text and literature citations. Do not capitalize a Latin preposition in the title unless it is the first word (e.g., “Viruses Effect in Vitro Propagation of Rose,” but “In Vitro Selection for Allelopathy in Tomato.”

All foreign languages that use alphabet characters other than Roman characters and their standard diacritical marks must be transliterated to English. Such languages include Slavic (including Russian), Hebrew, Arabic, Japanese, Korean, and Chinese. Although Greek characters are available (because Greek is used extensively in mathematics), modern Greek should be transliterated to English.
GENETIC TERMINOLOGY

Gene Names, Symbols, and Descriptions

Identify genes by name. The name should be short (one to three words) and describe the mutant form, if identifiable as such. Otherwise, it should identify the nonprimitive form unless it has been identified previously by long usage of the primitive form. Write the names of genes in italics in Latin or English; (e.g., male sterile). Capitalize the first word only if the mutant form is dominant (e.g., Early flowering). If one or more mimics exist and the same basic name is used, identify the gene further with a number following a hyphen (e.g., chlorophyll deficient-2).

Start the gene symbol with the first letter of the gene name, capitalized if dominant, followed by one or two letters to distinguish it from other symbols (e.g., Red, R; green flesh, gf; and green petal, gp). Identify multiple alleles by the symbol, followed by a letter or letters as superscript(s) (e.g., Redspotted, R; and Red-tinged, R').

Describe a gene in the text according to its phenotype, sufficiently to describe its effect(s), but as briefly as possible.

Linkage

Linkage information should include the names and symbols of the linked genes, the linkage detection $\chi^2$ value and probability, the recombination value and standard error, the phase (coupling or repulsion), the heterogeneity $\chi^2$ value (if more than one population was studied), and the type of population(s) studied (F2 or BC).

GEOGRAPHY

Always spell out the names of countries, states (in the United States), or provinces (in Canada) when they stand alone (e.g., there is no city cited). Use U.S. post office abbreviations for states and provinces when they are given with the city or county.
Leave a space between the numerical value and the symbol (e.g., “10 g,” not “10g”). In a series of measurements, give the unit (except for the percent sign) at the end (e.g., “3 to 10 °C” or “3, 6, and 9 m” but “10%, 59%, and 104%”).

Preferred style for some forms of measurement and abbreviation is indicated in the “Acronyms, Abbreviations, and Symbols” table; these style preferences are maintained to avoid symbol confusion.

**ACRONYMS, ABBREVIATIONS, AND SYMBOLS**

Abbreviations and symbols save space and, when used with discretion in the text, simplify complex expressions. Acronyms are words formed from the initial letter of each of the successive parts or major parts of a compound term; they are considered abbreviations in this manual. Symbols are arbitrary or conventional signs to represent operations, quantities, elements, relations, or qualities. Correct usage of symbols is important because an incorrect symbol may change the entire meaning of a quantity.

Use an abbreviation or symbol for a standard unit of measurement in the text only if the unit is preceded by a number (see “Measurements and Units” for accepted uses of abbreviations). Do not abbreviate units of measurement when they appear by themselves in the text (e.g., “the % of the concn used was the same for both trials” is incorrect (spell out “%” and “concn”). Spell out the name of a unit of measurement that follows a spelled-out number, as at the start of a sentence (e.g., “Nine milligrams is a lethal dose”).

Certain abbreviations (such as those for organic chemicals and standard procedures) are not acceptable without explanation. Define such abbreviations at the first mention by following the written-out term with the abbreviation enclosed in parentheses [e.g., “1 H-indole-3-acetic acid (IAA)” and “thin-layer chromatography (TLC)”; use the abbreviation thereafter. Likewise, identify in parentheses symbols that have yet to achieve common usage when first introduced and reidentify, if necessary, to avoid confusion with similar symbols [e.g., newtons and nitrogen share the same symbol (N)]. Use standard or widely accepted abbreviations in tables and figures, if necessary, for format considerations. Avoid using abbreviations in titles of papers.

Do not letter space the uppercase abbreviations for chemical expressions (e.g., TAA), organizations (e.g., ANSI), or government agencies (e.g., NIH). “ASHS” may be used on the first reference, without full name, except in byline addresses.

Letter space the parts of a lowercase abbreviation of a compound term only if no period is between them (e.g., “et al.,” and “sp gr”—but “a.i.,” “i.e.,” and “gen.nov.” Lowercase abbreviations of many compound terms are written without periods and without spaces between the parts (e.g., “mp” and “df”).
Do not italicize abbreviations of Latin terms; periods follow only the terms abbreviated. For example, “et alla,” “et cetera,” “id est,” and “exempli gratia” are abbreviated “et al.,” “etc.,” “i.e.,” and “e.g.,” respectively. Use “et al.” to indicate additional authors, not “etc.” The abbreviation “e.g.” precedes an example; the abbreviation “i.e.” precedes a clarification. A pair of commas separates “i.e.” and “e.g.” from their references.

### Acronyms, Abbreviations, and Symbols

<table>
<thead>
<tr>
<th>Word/unit</th>
<th>Abbrev./symbol</th>
<th>Accepted usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>active ingredient</td>
<td>a.i.</td>
<td>all uses</td>
</tr>
<tr>
<td>analysis of variance</td>
<td>ANOVA</td>
<td>second and subsequent uses</td>
</tr>
<tr>
<td>asterisk</td>
<td>*</td>
<td>use only for levels of significance within tables, not for footnotes.</td>
</tr>
<tr>
<td>at</td>
<td>@</td>
<td>spell out, do not use symbol except for e-mail</td>
</tr>
<tr>
<td>average</td>
<td>avg</td>
<td>table column heads only</td>
</tr>
<tr>
<td>base pair</td>
<td>bp</td>
<td>second and subsequent uses</td>
</tr>
<tr>
<td>by (dimension, interaction)</td>
<td>×</td>
<td>all uses</td>
</tr>
<tr>
<td>chilling injury</td>
<td>CI</td>
<td>second and subsequent uses</td>
</tr>
<tr>
<td>chi square value</td>
<td>$\chi^2$</td>
<td>statistical reporting</td>
</tr>
<tr>
<td>coefficient of determination</td>
<td>$R^2$, $r^2$</td>
<td>statistical reporting; $R^2$ for three or more variables, $r^2$ for two variables (italics)</td>
</tr>
<tr>
<td>coefficient of variation</td>
<td>cv</td>
<td>all uses</td>
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<tr>
<td>colony-forming units</td>
<td>cfu</td>
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<td>Co.</td>
<td>when used as part of a proper noun</td>
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<td>concn</td>
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<td>controlled atmosphere</td>
<td>CA</td>
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<td>crossed with</td>
<td>x</td>
<td>lowercase</td>
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<td>cross species</td>
<td>×</td>
<td>(math ×, no space between the symbol and the specific epithet)</td>
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<td>(interspecific hybrid)</td>
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<td>cultivar(s)</td>
<td>cv., cvs.</td>
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<td>Term</td>
<td>Abbreviation</td>
<td>Notes</td>
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<td>------------------------------------</td>
<td>--------------</td>
<td>--------------------------------------------</td>
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<td>experiment</td>
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<td>Fig(s).</td>
<td>with numerals only</td>
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<td>F₁, F₂</td>
<td>all uses (with subscripts)</td>
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<td>GLC</td>
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<td>with numerals only</td>
</tr>
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<td>logarithm, natural</td>
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<td>with numerals only</td>
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<tr>
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<td>M.</td>
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</tr>
<tr>
<td>Malling–Merton</td>
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<td>followed by period (e.g., M.M.106)</td>
</tr>
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<td>X, Y</td>
<td>statistical reporting (uppercase under bar)</td>
</tr>
<tr>
<td>modified atmosphere</td>
<td>MA</td>
<td>second and subsequent uses</td>
</tr>
<tr>
<td>month</td>
<td>mo.</td>
<td>tables and graphs only</td>
</tr>
<tr>
<td>nonsignificant</td>
<td>NS</td>
<td>tables and footnotes only</td>
</tr>
<tr>
<td>number</td>
<td>no.</td>
<td>with numerals; in table column heads, do not use #</td>
</tr>
<tr>
<td>number of observations in a sample</td>
<td>n</td>
<td>statistical reporting</td>
</tr>
<tr>
<td>number of observations in the population</td>
<td>N</td>
<td>statistical reporting</td>
</tr>
<tr>
<td>osmotic potential</td>
<td>Ψₛ</td>
<td>second and subsequent uses</td>
</tr>
<tr>
<td>outside diameter</td>
<td>o.d.</td>
<td>all uses</td>
</tr>
<tr>
<td>parental generations</td>
<td>P₁, P₂</td>
<td>all uses (with subscripts)</td>
</tr>
<tr>
<td>photosynthesis (net)</td>
<td>Pₙ</td>
<td>second and subsequent uses</td>
</tr>
<tr>
<td>Term</td>
<td>Abbreviation</td>
<td>Style and Usage Notes</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>photosynthetically active radiation</td>
<td>PAR</td>
<td>second and subsequent uses; note italics</td>
</tr>
<tr>
<td>photosynthetic photon flux</td>
<td>PPF</td>
<td>second and subsequent uses; note italics</td>
</tr>
<tr>
<td>plant introduction</td>
<td>PI</td>
<td>all uses</td>
</tr>
<tr>
<td>polyvinyl chloride</td>
<td>PVC</td>
<td>second and subsequent uses</td>
</tr>
<tr>
<td>probability</td>
<td>P</td>
<td>with numerals only (italic)</td>
</tr>
<tr>
<td>randomly amplified polymorphic DNA</td>
<td>RAPD</td>
<td>second and subsequent uses; do not use RAPDs, instead use RAPD markers</td>
</tr>
<tr>
<td>relative humidity</td>
<td>RH</td>
<td>with numerals only; second and subsequent uses</td>
</tr>
<tr>
<td>restricted fragment length polymorphism</td>
<td>RFLP</td>
<td>second and subsequent uses; plural—RFLPs—okay</td>
</tr>
<tr>
<td>sample coefficient of linear correlation</td>
<td>r</td>
<td>statistical reporting (italic)</td>
</tr>
<tr>
<td>scanning electron microscopy</td>
<td>SEM</td>
<td>second and subsequent uses not abbreviated in abstract</td>
</tr>
<tr>
<td>simple sequence repeats</td>
<td>SSR</td>
<td></td>
</tr>
<tr>
<td>species</td>
<td>sp.</td>
<td>formal nomenclature only; spell out in titles (singular and plural)</td>
</tr>
<tr>
<td>standard deviation of a sample</td>
<td>SD</td>
<td>all uses</td>
</tr>
<tr>
<td>standard error of the mean of a sample</td>
<td>SE</td>
<td>all uses</td>
</tr>
<tr>
<td>stomatal conductance</td>
<td>g_s</td>
<td>second and subsequent uses (note italics for “g”)</td>
</tr>
<tr>
<td>Student’s t statistic</td>
<td>t</td>
<td>statistical reporting (italic)</td>
</tr>
<tr>
<td>subspecies</td>
<td>ssp.</td>
<td>formal nomenclature only (singular and plural)</td>
</tr>
<tr>
<td>temperature</td>
<td>temp</td>
<td>table column heads only</td>
</tr>
<tr>
<td>thin-layer chromatography</td>
<td>TLC</td>
<td>second and subsequent uses</td>
</tr>
<tr>
<td>transmission electron microscopy</td>
<td>TEM</td>
<td>second and subsequent uses</td>
</tr>
<tr>
<td>ultraviolet</td>
<td>UV</td>
<td>second and subsequent uses</td>
</tr>
<tr>
<td>variance ratio</td>
<td>F</td>
<td>statistical reporting (in an analysis of variance)</td>
</tr>
<tr>
<td>volume (mix ratio)</td>
<td>v/v</td>
<td>with numerals only</td>
</tr>
<tr>
<td>volume (space)</td>
<td>vol</td>
<td>table column heads only; no period</td>
</tr>
<tr>
<td>weight</td>
<td>wt</td>
<td>only in tables and graphs</td>
</tr>
<tr>
<td>wettable powder</td>
<td>WP</td>
<td>second and subsequent uses, with percents</td>
</tr>
<tr>
<td>year</td>
<td>yr</td>
<td>table column heads only</td>
</tr>
</tbody>
</table>
### SI Units and Prefixes

<table>
<thead>
<tr>
<th>Word/unit</th>
<th>Abbrev./symbol</th>
<th>Accepted usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>bar</td>
<td></td>
<td>do not use; convert to SI unit: 1 bar + 0.1 MPa = 100 kPa</td>
</tr>
<tr>
<td>Becquerel</td>
<td>Bq</td>
<td>derived SI unit for radioactive disintegrations per second</td>
</tr>
<tr>
<td>Brix</td>
<td>°Brix</td>
<td>with numerals only; use only with syrups, use soluble solids concentration (%) for juices extracted from plant tissues</td>
</tr>
<tr>
<td>Celsius</td>
<td>°C</td>
<td>all uses</td>
</tr>
<tr>
<td>centimeter</td>
<td>cm</td>
<td>with numerals only</td>
</tr>
<tr>
<td>cubic centimeter</td>
<td>cm³</td>
<td>with numerals only, equivalent to 1 mL</td>
</tr>
<tr>
<td>cubic decimeter</td>
<td>dm³</td>
<td>equivalent to 1 L</td>
</tr>
<tr>
<td>cubic meter</td>
<td>m³</td>
<td>with numerals only</td>
</tr>
<tr>
<td>Curie</td>
<td>Ci</td>
<td>do not use; covert to GBq (1 Ci = 37 GBq)</td>
</tr>
<tr>
<td>Dalton</td>
<td>Da</td>
<td>use the SI unit u, the unified atomic mass unit, which is exactly equivalent to the Dalton; define u at first use</td>
</tr>
<tr>
<td>day</td>
<td>d</td>
<td>all uses, not abbreviated in abstract</td>
</tr>
<tr>
<td>degree (angular)</td>
<td>°</td>
<td>with numerals only</td>
</tr>
<tr>
<td>decisiemens</td>
<td>dS</td>
<td>with numerals only</td>
</tr>
<tr>
<td>decimeter</td>
<td>dm</td>
<td>SI unit for 10⁻¹ m</td>
</tr>
<tr>
<td>diameter</td>
<td>diam</td>
<td>table column heads only</td>
</tr>
<tr>
<td>disintegrations per minute</td>
<td>dpm</td>
<td>do not use, see Becquerel</td>
</tr>
<tr>
<td>eigen volt</td>
<td>eV</td>
<td>with numerals only</td>
</tr>
<tr>
<td>Einstein</td>
<td>E</td>
<td>a discarded unit for mole of photons; use µmol m⁻²s⁻¹</td>
</tr>
<tr>
<td>gram</td>
<td>g</td>
<td>with numerals only</td>
</tr>
<tr>
<td>grams per cubic centimeter</td>
<td>g·cm⁻³</td>
<td>Preferably use g·mL⁻¹ or g·L⁻¹</td>
</tr>
<tr>
<td>gravity</td>
<td>gₙ</td>
<td>force of gravity, average of earth’s surface (italicize g only); no times (×) needed; use for centrifugation</td>
</tr>
<tr>
<td>Gray</td>
<td>Gy</td>
<td>SI-derived unit for absorbed radiation dose (J·kg⁻¹); 1 Gy = 100 rads (an obsolete unit)</td>
</tr>
<tr>
<td>hectare</td>
<td>ha</td>
<td>with numerals only</td>
</tr>
<tr>
<td>hertz</td>
<td>Hz</td>
<td>with numerals only</td>
</tr>
<tr>
<td>hour (unit)</td>
<td>h</td>
<td>with numerals; not abbreviated in abstract</td>
</tr>
<tr>
<td>joule</td>
<td>J</td>
<td>with numerals only</td>
</tr>
<tr>
<td>Kelvin</td>
<td>K</td>
<td>SI base unit for temperature; note not °K</td>
</tr>
<tr>
<td>Unit</td>
<td>Abbreviation</td>
<td>Notes</td>
</tr>
<tr>
<td>----------------------------</td>
<td>--------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>kilodalton</td>
<td>kDa</td>
<td>with numerals only</td>
</tr>
<tr>
<td>kilogram</td>
<td>kg</td>
<td>with numerals only</td>
</tr>
<tr>
<td>kilolux</td>
<td>klx</td>
<td>with numerals only</td>
</tr>
<tr>
<td>kilometer</td>
<td>km</td>
<td>with numerals only</td>
</tr>
<tr>
<td>kilovolt</td>
<td>kV</td>
<td>with numerals only</td>
</tr>
<tr>
<td>krad</td>
<td></td>
<td>do not use; see Gray</td>
</tr>
<tr>
<td>liter(s)</td>
<td>L</td>
<td>with numerals only</td>
</tr>
<tr>
<td>lux</td>
<td>lx</td>
<td>with numerals only</td>
</tr>
<tr>
<td>megagram</td>
<td>Mg</td>
<td>with numerals only</td>
</tr>
<tr>
<td>meter</td>
<td>m</td>
<td>with numerals only</td>
</tr>
<tr>
<td>metric ton (tonne)</td>
<td>t</td>
<td>with numerals only</td>
</tr>
<tr>
<td>microequivalent</td>
<td>µeq</td>
<td>with numerals only</td>
</tr>
<tr>
<td>microgram</td>
<td>µg</td>
<td>with numerals only</td>
</tr>
<tr>
<td>microliter</td>
<td>µL</td>
<td>with numerals only</td>
</tr>
<tr>
<td>micrometer (formerly, micron)</td>
<td>µm</td>
<td>with numerals only</td>
</tr>
<tr>
<td>micromolar</td>
<td>µM</td>
<td>with numerals only</td>
</tr>
<tr>
<td>micromole</td>
<td>µmol</td>
<td>with numerals only</td>
</tr>
<tr>
<td>milliequivalent</td>
<td>meq</td>
<td>with numerals only</td>
</tr>
<tr>
<td>milligram</td>
<td>mg</td>
<td>with numerals only</td>
</tr>
<tr>
<td>milliliter</td>
<td>mL</td>
<td>with numerals only</td>
</tr>
<tr>
<td>millimeter</td>
<td>mm</td>
<td>with numerals only</td>
</tr>
<tr>
<td>millimolar</td>
<td>mM</td>
<td>with numerals only</td>
</tr>
<tr>
<td>millimole</td>
<td>mmol</td>
<td>with numerals only</td>
</tr>
<tr>
<td>millivolt</td>
<td>mV</td>
<td>with numerals only</td>
</tr>
<tr>
<td>minute (time)</td>
<td>min</td>
<td>may be used with SI, but use the second whenever appropriate; use only with numerals and in table column heads</td>
</tr>
<tr>
<td>molar</td>
<td>M</td>
<td>with numerals only; use for growth regulators</td>
</tr>
<tr>
<td>mole</td>
<td>mol</td>
<td>with numerals only</td>
</tr>
<tr>
<td>nanoliter</td>
<td>nL</td>
<td>with numerals only</td>
</tr>
<tr>
<td>nanometer</td>
<td>nm</td>
<td>with numerals only</td>
</tr>
<tr>
<td>nm⁻¹</td>
<td></td>
<td>spectral irradiance (moles of photons) per unit wavelength within a specified range</td>
</tr>
<tr>
<td>nanosecond</td>
<td>ns</td>
<td>with numerals only</td>
</tr>
<tr>
<td>Newton</td>
<td>N</td>
<td>with numerals only; derived SI unit for force; do not use kg per unit area (1 kg mass exerts a force of 9.8 N on earth’s surface)</td>
</tr>
<tr>
<td>normal (gram-equivalents per liter)</td>
<td>N</td>
<td>with numerals only</td>
</tr>
</tbody>
</table>
Air Flow

According to Savage (1979, p. 495), wind speed has the units m·s⁻¹, mm·s⁻¹, or µm·s⁻¹. The km·h⁻¹ unit is not preferred. State the height above surface when reporting results in field studies because wind speed varies with this value. In controlled environments, reference to the volume of air movement per unit time or the volume rate of air movement is more meaningful. The unit of this quantity is m³·s⁻¹.

Application Rates

Application rates are reported in kilograms (or grams, milligrams, or micrograms if more appropriate) per square meter (kg·m⁻²) for applications of dry materials (such as seed, pesticide, and fertilizer) in small experimental plots. For large-scale applications, report kilograms per hectare (kg·ha⁻¹), although the hectare (10⁴ m²) is not a recommended multiple of a basic SI unit. For liquid applications to small and large plots, report liters per square meter (L·m⁻²) or liters per hectare (L·ha⁻¹), respectively. When volume may be important, report liters per cubic meter (L·m⁻³).

Centrifugation

Use \( g_n \). Italicize the “g” only. Example: The sample was centrifuged at 20,000 \( g_n \).
Concentration
Expressing concentration in parts per million (ppm) or parts per billion (ppb) is acceptable, but not preferred, because the terms are ambiguous. When the molecular mass of a substance is known, report concentration as moles per kilogram (mol·kg⁻¹), moles per cubic meter (mol·m⁻³), or moles per liter (mol·L⁻¹). When molecular mass is unknown, report concentrations as milligrams per kilogram (mg·kg⁻¹), milligrams per cubic meter (mg·m⁻³), or milligrams per liter (mg·L⁻¹). Use the small capital letters N and M (indicated by double-underscoring) to indicate normal and molar concentrations, respectively (e.g., 2 N NaSO₄). For dilute solutions, use µM (e.g., 1.0 µM), rather than 10⁻⁶ M. Use the decimal system, or multiplier of 10, for units of concentration (e.g., 0.1 M or 0.1 mol·L⁻¹, not M/10). Avoid percentage expressions, but when using solution percentages, indicate v/v or w/v.

Exchange Capacity
Give exchange capacity and exchangeable ion composition in equivalents (eq) or milliequivalents (meq) per gram (these are preferred.). If the cation exchange capacity is determined by the single ion saturation technique, the ion used should be specified because it can affect the cation exchange capacity measured.

Frequency
Frequency may be expressed as the hertz (Hz) or the reciprocal second (s⁻¹), which are equivalent. Hertz is preferred for frequency of light or other electromagnetic radiation, whereas the reciprocal second is preferred for rotational frequency. Revolutions per second (r·s⁻¹) is preferred to revolutions per minute (rpm) because minute is not a basic SI unit.

Gauge
Always give actual dimension (e.g., “the wire was 0.13 mm thick”). Gauge numbers are meaningless to many readers, as there are several systems.

Heat Quantities
Express specific latent heat as joules per kilogram (J·kg⁻¹). Express heat flux as joules per second (J·s⁻¹) or the watt (W). Heat flux density is the rate of energy of change per unit area J·s⁻¹·m⁻²; however, watts per square meter (W·m⁻²) is used more often in the United States.

Length
The SI unit of length is the meter (m). The micron and the millimicron have been replaced by the micrometer (µm) and the nanometer (nm), respectively.
Light
See “Photosynthetic radiation.”

Magnification
The multiplication sign should precede the level in expressions of power of magnification with no space between (e.g., ×400).

Mass
See “Weight.” Weight varies with the force of gravity, whereas mass is independent of gravity. However, many journals, including ASHS publications, continue to use weight.

Mix Ratios
Do not use slant lines to express ratios (e.g., “3/2” should be expressed as “3:2” with no spaces before or after the colon). There is an exception to this rule: the mix ratios “w/v” and “v/v” are permissible when describing quantity-to-quantity amounts). When giving the media mix ratio for containers, use the following style: “1 sand : 1 clay : 1 sphagnum peat (by volume).” Note the spaces on either side of the colons. Use “by volume,” not “v/v/v.” Use “w” and “v” (for weight and volume, respectively) in mix ratios only.

Monetary
If monetary units are necessary to report crop yield values, the value in U.S. dollars should be reported first, with the local equivalent following in parentheses. Express values less than $1 decimally (e.g., $0.80)—although 80¢ is permissible.

Percent
The percent sign (%) is used with numerals only; otherwise, the term “percent” is written out, as one word. Use the percent sign in a series of percentages (e.g., “tested at the 1%, 5%, 10%, and 20% levels.” Use the percent sign with each of a series of numbers if they precede the object (e.g., “There was no change when plants were sprayed with the 5% or the 8% solutions.” Repeat the percent sign when giving a range (e.g., “30% to 50%”). Do not average data expressed in percentages.

Photosynthetic Radiation
While commonly used as a unit for photosynthetically active radiation (PAR), the einstein (E) is not an SI unit. SI units of micromoles per square meter per second (µmol·m⁻²·s⁻¹) are equivalent and should be used. Photosynthetic photon flux (PPF) is photon flux in the 400- to 700-nm waveband. For studies with other wavebands, the waveband should be specified.
**Precipitation**
   Should be in millimeters (water depth).

**Pressure**
   The SI unit of pressure is the pascal (Pa) or newtons per square meter (N·m⁻²). Do not use kilograms per meter (kg·m⁻¹) or pounds per square inch (psi) for pressure readings. Instruments do not measure or test pressure and should not be called “pressure testers”; they should be referred to as penetrometers or firmness testers.

**Relative Humidity**
   Relative humidity is the ratio of specific humidity to the saturation specific humidity, expressed as a percentage. The unit of relative humidity is the percent. If the term “specific humidity” is preferred, then the units g·kg⁻¹ may be used.

**Sieve Size**
   Give pore dimension or the number of pores per unit area.

**Temperature**
   Generally, the term “temperature” is meaningless—an adjective must accompany the word. For example, we speak of “leaf temperature,” “soil temperature,” or “air temperature.” Each of these temperatures is defined carefully so as not (in the case of air and leaf temperatures) to include the heating effects of the sun’s radiation. Report the type of sensor and location used for temperature readings. Temperatures may be “high” or “higher,” “low” or “lower,” but not “warm” or “warmer,” “cool” or “cooler.”
   The ASHS-preferred unit of temperature is in degrees Celsius (°C), not the SI unit the kelvin (K, not °K). Do not use the synonym “centigrade.”
   Use the symbol °C, with a degree sign, each time a temperature is mentioned. When reporting temperature in a series or in a range, use the symbol °C at the end (e.g., “20, 40, and 50 °C” or “18 to 24 °C.” When temperatures are separated in the sentence, use the symbol °C with each (e.g., “at 32.2 °C than at 21.1 °C”). Report day and night temperatures when needed (e.g., “27 °C day/13 °C night”).
   To avoid confusion with temperatures below 0 °C, do not use the range (en) dash with temperature readings (e.g., use “8 to 10 °C,” not “8–10 °C,” or use “–4 to –2 °C,” not “–4–2 °C”).

**Thickness**
   While used conventionally to give the thickness of plastic sheeting, mils are not SI units. Instead, use millimeters to give thickness of plastic or any other thin material.
Time

Two time systems are appropriate, depending on how the author wishes to designate time:

- The 24-h system is indicated by four digits, the first two for hours and the last two for minutes. The day begins at midnight denoted 0000HR, and the last minute of the day is 2359HR. Thus, 0830HR is the same as 8:30AM, 1245HR is the same as 12:45PM, and 2315HR is the same as 11:15PM. Use the small capitals HR to designate clock hours, as distinguished from the abbreviation used for quantitative hours (h).

- The 12-h AM/PM system sometimes leads to confusion; e.g., “12:00” can mean noon or midnight. Use the small capitals AM and PM to designate before and after noon, respectively. Indicate the time in minutes following the colon, even if it is zero; e.g., “3:00AM” is correct, rather than “3AM.” Do not use the contraction “o’clock” with abbreviations of time.

The abbreviations for time zones (GMT, EST, CDT, etc.) are irrelevant to most studies. If daylength is critical, do not imply it through time-zone abbreviations. Give daylength in quantitative hours (e.g., “11 h 22 min” with no comma) along with quality of daylight.

Abbreviate the terms “hour(s),” “minute(s),” and “second(s),” (h, min, and s, respectively) in table column headings and when used with a number in the text, but spell out in the abstract. Abbreviate the terms “year(s),” “month(s),” and “week(s)” (yr., mo., and wk., respectively) in table column headings only, but spell them out when used with a number in text (e.g., “the project was completed in 4 months and 3 weeks”).

Transpiration

Express transpiration as kilograms per square meter per second (kg·m⁻²·s⁻¹) on a mass basis and as cubic meters per square meter per second (m³·m⁻²·s⁻¹ or m·s⁻¹) on a volume basis.

Volume

The SI unit of volume is the cubic meter (m³). The unit cubic centimeter (cm³, not cc) is acceptable. Give the volume of all containers used in an experiment. Other dimensions can be added if relevant.

Water Potential

According to Savage (1979, p. 495), volumetric water potential is the potential (energy) needed to move a unit volume of water from the system under consideration to the reference position, normally taken to be that of pure free water at the same temperature as the water in the system and at a pressure of one standard
atmosphere, namely 101.3 kPa. Hence, the units of volumetric water potential are J·m⁻³, N·m⁻², or Pa. Alternatively, the term “specific water potential” has the same meaning as volumetric water potential, except that a unit mass of water is moved to the reference state and the unit is J·kg⁻¹. Volumetric water potential = \( \pi_w(T) \times \text{specific water potential} \) where \( \pi_w \) is the density of water at temperature T. Many authors state incorrectly that \( \pi_w = 1000 \text{ kg·m}^{-3} \), implying that it is a constant for all temperatures.

**Weight**

See also “Mass.” The unit of weight is the kilogram (kg). Weight can be expressed also in grams (g), milligrams (mg), micrograms (µg), etc. [Weight technically is a measure of force produced by gravity, and the proper unit is the newton (N), or gravitational attraction]. Do not combine fresh weight and dry weight with SI units. State separately, such as “Data were recorded on a fresh weight basis (g·kg⁻¹).

**Whole Numbers**

As a general rule, use Arabic numerals for whole numbers, but spell out numbers in the following cases: 1) when the number is below 10 and immediately precedes a non-SI unit of measure (e.g., “two plants” but “2 m,” “three trees” but “3 ha”), 2) when a number is used as a figure of speech (e.g., “a thousand times no”), 3) when numbers begin sentences (however, reword sentences to avoid starting with a number or a series of numbers, or end the preceding sentence with a semicolon), 4) when two numbers are adjacent to each other (e.g., write “thirty 10-L pots” instead of “30 10-L pots”), 5) in a series of three or more numbers all below 10 (e.g., “two, five, and nine cultivars,” but “6, 8, and 12 leaves,” and “three and 15 times”), 6) when a number is part of a proper name (except for cultivar names that include numbers), and 7) when the numbers 1 through 10 appear in titles of papers.

Use Arabic numerals with a unit or abbreviation of measure, including monetary units, proportions, rates, temperatures, percentages, dates, time, pages, and numerical designations such as “Expt. 3.” Use Arabic numerals for all mathematics where symbols are used (e.g., \( 3 \times 4 \)), where arithmetic function is discussed (e.g., “divide by 6”), and where exponents are used (e.g., \( 10^{10} \)).

Use Roman numerals only in literature citations when the original used Roman numerals.

In numbers consisting of two to four digits (through the “thousandth place”), run the numerals together (e.g., 2000 or 6891), but in tables where there are numbers consisting of four or more digits, place commas between each group of three digits (e.g., 1,000; 10,000; or 1,000,000).
Change numbers having several zeros by substituting a word (e.g., 7.8 million, not 7,800,000), using exponents (e.g., $10^6$, not 1,000,000), or changing the basic unit of measurement (e.g., 25 kg, not 25,000 g). You may use exponential functions to reduce numbers, particularly in tables and figures for space considerations.

Do not use full parentheses to list points numerically in a sentence or paragraph. Use closing parentheses only with numbers or lowercase letters to list points [e.g., “5)” or “d”].

Plurals of numbers, such as years, are formed without apostrophes (e.g., “the 1890s” or “6s and 7s”). Numbers in a series are separated by commas, with a comma preceding the last conjunction (e.g., “57, 14, 115, and 56”).

**Decimals**

Round off all decimals to no more than three significant digits. The period (not the comma) is used for the decimal point. Decimal figures less than 1 carry a zero before the decimal point (e.g., 0.16, not .16).

**Fractions**

Write fractions following a whole number or in a series with Arabic numerals and a slant line (e.g., $23 \frac{1}{2}$, or $1 \frac{1}{2} + 2 \frac{1}{2} + 2 \frac{1}{2}$). Spell out fractions when they stand alone (note hyphen) (e.g., “one-third,” “one-half,” and “two-fifths”). Use care in transposing common units such as one-half; e.g., if 1-1/2 pots of soil were used, do not write “l.5” unless measurement was accurate to one-tenth; conversely, if measurement was accurate, use decimals rather than fractions.

**Ordinal Numbers**

Follow the same rules as for whole numbers when using ordinals (e.g., “third tree” but “3rd year,” and “thirteenth” is “13th,” but “first week” and “first year”). When enumerating parts of an argument, using the words “secondly” or “thirdly” is poor grammar; one does not say “firstly.” Begin progressive clauses with the words “second,” “third,” “fourth,” etc.

**Range of Numbers**

When reporting ranges, “from 10 to 15” is preferred, but “range 10–15” (with en-dash) is acceptable.

**Rounding Off**

Use the following procedure for rounding a number in which three significant digits are to be retained:

- If the digit to the right of the third digit is less than 5, leave the third digit unchanged (e.g., 4.122 rounds to 4.12).
- If the digit to the right of the third digit is more than 5, increase the third digit by 1 (e.g., 4.128 rounds to 4.13).
- If the digit to the right of the third digit is exactly 5, followed only by zeros, and
the third digit is even, leave the third digit unchanged (e.g., 4.125 or 4.1250 rounds to 4.12).

If the digit to the right of the third digit is exactly 5, followed only by zeros, and the third digit is odd, increase the third digit by 1 (e.g., 4.135 or 4.1350 rounds to 4.14).

If the digit to the right of the third digit is 5 and there is at least one digit other than 0 to the right of the 5, increase the third digit by 1 (e.g., 4.1253 rounds to 4.13).

When rounding an inconveniently large number, follow a similar procedure (e.g., the number 2,845,492 can be expressed as 2.8 million).

**Significant Figures**

In reporting a number, the number of significant digits (those known to be reasonably reliable) must be commensurate with the precision of the experimental method. More than three significant digits rarely are justified in horticultural measurements. If the quantity must be converted to SI units, multiply the quantity by the exact conversion factor and then round to the appropriate number of significant digits.

A recorded value of 37 mL represents two significant digits (3 and 7). If this same volume were written as 0.037 L, it would still contain only two significant digits. Zeros appearing as the first digits of a number are not significant since they merely locate the decimal point; thus, the two zeros in the value 0.037 are not significant. The values 0.0370 L and 0.370 L, however, represent three significant digits (3, 7, and the last zero), the value 1.037 L represents four significant digits (1, 0, 3, and 7), the value 1.0370 L represents five significant digits (1, 0, 3, 7, and 0), and the value 37.00 L represents four significant digits (3, 7, and the two zeros).

Use only the number of significant figures that is justified by the precision of the least precise measurement and that is meaningful in the context of use (e.g., leaf area was 137.6 mm may be justified, but it is not meaningful. Use 138 mm).

Avoid exaggerated precision in statistical reporting. When reporting means, more than three significant digits rarely are justified. Also avoid exaggerated probability statements: computers can be programmed to provide probability statements with many significant digits, but these are based on assumptions that are never met exactly in actual practice.

**Yield**

Report crop yields in kilograms per hectare (kg·ha⁻¹), megagrams per hectare (Mg·ha⁻¹), or tonnes per hectare (t·ha⁻¹).
**PUNCTUATION**

Proper punctuation marks emphasize the relationship among words and word groups. Although the current tendency is to avoid unnecessary punctuation, overpunctuation is preferred to ambiguity. Often sentences can be rewritten or divided into two or more sentences.

The following sections describe proper usage of punctuation in ASHS publications but are not meant to be a full treatment of punctuation in English usage.

**Apostrophe**

Do not use an apostrophe to indicate the omission of a letter or letters in contractions (e.g., use “Assn.,” not “Ass’n”). Most contractions (can’t, rec’d, he’s) are undesirable in scientific writing.

Do not use an apostrophe with a personal pronoun in the possessive case (e.g., “its” and “hers”).

Do not use an apostrophe or an “s” when making symbols plural (e.g., “SDs” for standard deviation(s), not “SD’s”).

Do not use apostrophes for prime and minute symbols.

**Brackets**

Use brackets for the following:

- To enclose material (such as an editor’s note) that has been inserted in a quotation.
- To enclose material that already contains material in parentheses, such as a scientific name with more than one authority; e.g., “peach [Prunus persica (L.) Batsch] has the …”).
- To enclose equation numbers: \( x + y = z \) [1]
- For additional brackets, use the following order: \{ [ ( ) ] \}

**Capitals**

Capitalization should follow standard English usage [e.g., for the first word of each complete sentence, for proper nouns (names), and for the first word of an independent clause following a colon].

In addition, use initial capitals for the following:

- The first word and proper nouns and adjectives in the title of an article or book when cited in the text; but only the first word of the title when listed in literature citations.
- A professional, civil, military, or religious title that immediately precedes a personal name (e.g., Senator Jackson, Captain Hornblower).
**Do not** use initial capitals for the following:
- Names of subject fields for which a degree is given (unless the subject is a language).
- Words derived from proper names but now in common usage (e.g., bunsen burner, petri dish).
- Seasons of the year (e.g., spring) unless referring to a specific season (e.g., Spring 1997).
- Professional titles when not preceding a name (e.g., assistant professor). Second and/or subsequent words of a hyphenated term when the first word is capitalized. 

See sections on Geography, Trade names, and Taxonomy for specific examples in those areas.

**Colon**

Use a colon to mean “note what follows,” especially after expressions like “as follows” or “the following.” A colon should fall at the end of, not in the middle of, a thought. **A colon should not precede a verb or preposition.**

**YES** We collected several plant parts: leaves, shoots, and stems.

**NO** We collected: leaves, shoots, and stems.

Use a colon to separate the parts of ratios (except for quantity-to-quantity mix ratios, where the slant line is used), proportions, and dilutions (e.g., “1:3” for “1 part to 3 parts” or “1 part in 3 parts”). There is a space before and after the colon when the number precedes the ingredient (e.g., “1 sand : 1 clay : 1 sphagnum peat”).

A colon should fall outside a closing parenthesis or closing quotation mark.

**Comma**

Use a comma for the following:

To separate the elements (words, phrases, or clauses) of a simple series of three or more items, including the element preceding the conjunction (e.g., “apples, peas, or oranges” and “the tomatoes wilted, the beans died, and the peppers bore no fruit”). If any of the elements contain internal punctuation, separate them with semicolons.

Use a comma also to set off a conjunctive adverb (such as “therefore,” “thus,” “since,” “however,” and “accordingly”) or a transitional phrase (such as “in fact,” “after all,” and “on the contrary”) that introduces a distinct break in continuity of thought.

Commas belong outside a closing parenthesis and inside a closing quotation mark, unless the quoted material is the name of a cultivar.

Use a comma inside the closing quotation mark when a sentence continues beyond the end of a quotation, even though the comma is not part of the quotation.

Do not use a comma for the following:
- Between the month and year (e.g., “June 1983,” not” June, 1983”).
- In numbers of four digits (e.g., “6981,” not “6,981”).
Dash, em

The em-dash is used (sparingly) to indicate an abrupt break in thought within a sentence (e.g., “Federal funds allocated to the states—except for funds reserved for cooperative region research—are determined by a formula based on the size of the rural population in each state”).

Dash, en

The en-dash is used to indicate range (e.g., “p. 7–13”), joining of two nouns (e.g., “soil–air interaction”), compounding of capitalized names (e.g., “Chicago–Moscow night”), and fertilizer components (e.g., “10N–3P–83K”).

Do not use a minus sign or the word “from” with an en-dash (e.g., use “–3 to –6 °C,” not “–3––6 °C,” and use “from page 8 to 11,” not “from page 8–11”).

Diacritical Marks

Retain diacritical marks in authors’ names, street addresses, and literature citations. Do not use them for names of cities and countries, unless there is no English equivalent (e.g., use “Spain,” not “España,” or use “Cologne,” not “Koln”).

HYPHENATION, COMPOUND TERMS

Compound Terms

A compound term is a combination of two or more words that, through use together, have acquired a special meaning. Use a hyphen for noun–adjective expressions, such as “on a per-gram basis” and when it adds clarity. Avoid over-use—if clear without a hyphen, leave out (e.g., dry weight basis).

Adverbs

Never use a hyphen for a two-word modifier if the first word ends in “ly” or if the word is “very” (e.g., “freshly harvested tomatoes” and “very high frequency”).

Modifiers

Hyphenate compound adjectives before the word they modify but not after the word (e.g., “split-plot design,” but “each split plot,” or “a winter-hardy plant,” but “it is winter hardy,” or “a 5-mL drench,” but a “drench of 5 mL,” or “a 12-h cycle,” but “every 12 h.” A compound modifier containing a numeral or spelled-out number usually is hyphenated (e.g., “two-thirds majority,” “a 4-min exposure,” and “5-year-old field.”)
Open compound nouns

Open compound nouns that are well established and widely used in a field usually are not hyphenated (e.g., “stem rust control” or “red kidney bean”).

Use a hyphen (which is not as long as an en-dash) for the following:

• Between a prefix and a proper noun or name (e.g., “pre-Renaissance”).
• Between elements of a unit modifier in attributive position to avoid ambiguity (e.g., “he is a small-business entrepreneur”—to avoid the connotation that he is a business entrepreneur of small stature).
• Suspend the first part of a hyphenated, compound modifier when used with another hyphenated, compound modifier (e.g., “a 6- or 8-d interval”—note the space following the hyphen after “6”). Also, the elements in a series carry a hyphen if they are modifiers (e.g., “20-, 30-, and 40-cm depths”).
• Between the numerator and denominator of a spelled-out fraction (e.g., “one-third”).
• To break a chemical name at the end of a line, only if the hyphen is a part of the name.
• For place keeping in tables where data have been excluded (use three hyphens). Do not use a hyphen for the following:
  • To divide a word at the end of a line in a typed manuscript—go to the next line.
  • After adverbs ending in “ly” or before words preceded by the adjective “very.”
  • In measurements where the preposition “of” is understood (e.g., do not write “5-mL water” for “5 mL [of] water”).
• With prefixes such as “re-,” “non-,” “pre-,” “post-,” and “sub,” except in the cases of multiple prefixes or where the meaning of the word would be understood (e.g., re-cover a canopy vs. recover from an illness). When it is necessary to break a chemical name between lines in a manuscript (instead, use the close-up symbol).

**air-conditioning**  air-condition (verb), air-conditioned (adjective), and air conditioner (noun).

**by-product**

**clear-cut**

**cool-white**

**co-worker**

**-fold**  denotes multiplication by the root. It is hyphenated and roots are given in Arabic numerals [e.g., “12-fold” (“twelve-fold” and “12fold” are incorrect).

**4-H**

**-like**  not hyphenated, unless the suffix follows a word ending in “ll” (e.g., “shell-like”), a long word (e.g., “picuropucumonia-like”), a proper name (e.g., “June-like”), a hyphenated word (e.g., “half-ape-like”), or when it is used as a modifier (e.g., “doll-like appearance,” “animal-like behavior”).
one-half, two-thirds, etc.
peat-lite
root-knot nematode
water-holding capacity
year-round

**Italics**

Use italics for the following:

- The scientific name of a genus, species, or subspecies, but not for the names of higher taxa. Italicize all scientific trinomials of plants and organisms (but not the authorities).
- The titles of books, journals, or other published works when they are mentioned in the text or footnotes, but not when they are listed in literature citations.
- Latin and foreign words and descriptive phrases that have not been naturalized in English (see “Foreign Words,” page 33).
- A word or phrase given stress or emphasis. Overuse of italics for this purpose, however, destroys the emphasis. Where italics are added for stress within quotations, include a parenthetical note between the end of the quotation and the period [e.g., “‘Only results of original research are acceptable’ (italics mine)’]. A word or phrase discussed as a term or introduced for specific discussion is not italicized but is enclosed in double quotation marks.
- An unknown or a constant in mathematical equations, some statistical variables or functions, and symbols for certain physical properties (e.g., $g$ for gravity, $P$ for probability, and $r$ for sample coefficient of linear correlation).
- Prefixes, symbols, or letters designating configurations of the chemical structure of organic compounds used for pesticides. Examples include: hyphenated prefixes ($cis$-, $trans$-, but not bis- and tris-), elements that occur as locants ($O$, $S$, $N$, $H$), and configurational relationships ($R$, $S$).
- Names of genes and gene descriptions (e.g., $af$ and $rin$). Also, the symbols when referring to chromosome number (e.g., somatic number ($2n = 56$), gametic number ($n = 28$), and genomic number ($x = 7$).

Do not use italics for complete quotations in a foreign (non-English) language.

**Parentheses**

Use parentheses to enclose the name of the author of the original taxonomic description when a species is transferred to a genus other than the one to which it was assigned originally.

Use a closing parenthesis to enumerate points in a sentence [e.g., “(a)...(b)...(c)...” or “(1)...(2)...(3)...” or to set off the number or letter of an enumerated paragraph that begins a line. Do not label enumerations unless the
labels are necessary for clarification or speed of reading.

Do not use parentheses within parentheses; use em-dashes or parentheses within brackets instead.

**Period**

Periods are used to end a sentence or indicate an abbreviation. They belong inside of quotation marks, unless the quoted material is the name of a cultivar.

Use a period for the following:
- To abbreviate the name of a state (but not with official ZIP code abbreviations) (e.g., “Conn.,” but “CT”).
- To abbreviate a Latin term (e.g., “e.g.” and “sp.nov”).
- In an abbreviation in which omission of the period might cause confusion (e.g., “Fig.” and “ed.”).
- At the end of paragraph side heads.

Do not use a period for the following:
- After elements of abbreviations for academic degrees (e.g., “BA” and “PhD”).
- With a lowercase contraction or abbreviation (except Latin) commonly acceptable in scientific or technical writing (e.g., “concn,” “diam,” “mm,” and “g,” but “Expt.” and “cv.”).
- After main headings in the text.
- After table subentries and table column headings (unless the entry or heading is, or ends with, an abbreviation that requires a period).
- After an item in a list (unless the item completes a sentence whose beginning is the heading of the list or ends with an abbreviation that requires a period).

**Quotation Marks**

**Use double quotation mark for the following:**

Around text that is a direct, literal quotation from a published source. Do not italicize direct quotations. Personal communication is considered unpublished material and does not require quotation marks.

Around the title of an article, the title of a chapter, or other part of a book, and the title of a series when referred to in the text or footnotes (such titles are neither italicized nor enclosed in quotation marks in the literature cited).

Around the first appearance of a term or word that is being a) coined or introduced for the first time; b) defined or discussed as a term or word; or c) adopted from another field, applied in a new or unusual sense, or given a special meaning.

**Use single quotation mark for the following:**

For cultivar names in the text, footnotes, table headnotes and footnotes, and figure captions (except where the abbreviation “cv.” or the word “cultivar” immediately precedes the name), but not in table headings, table fields, or bodies of
figures, except where omission of the single quotes would reduce comprehension.

Reproduce quotations of material that contain factual or typographical errors with those errors intact, drawing attention to the error or correcting it within the quote in brackets. When material has been combined from a quotation for clarity, use the ellipsis (...) to show the deletion.

Place commas and periods within quotation marks, even if they are not part of the quotation, except when the quoted material is the name of a cultivar. Place semicolons and colons outside quotation marks.

**Small Capitals**

Small capitals give typographic variety or help distinguish certain abbreviations from others having identical letters. Use small capitals for the following abbreviations: SE (standard error of the mean of a sample), SD (standard deviation of a sample), LSD (least significant difference), HSD (honestly significant difference), NS (nonsignificant), CV (coefficient of variation), HR (24-h time), AM (before noon), PM (after noon ), BC (before Christ), AD (anno Domini), N (normal concentration), and M (molar concentration). Rotation of the chemical structure of organic substances used for pesticides is shown with small capitals D and L.

**Soil Identification and Terminology**

Identify the soil used in field experiments at the lowest possible taxonomic level. As a general guideline, identify soils at the series and family levels (e.g., “the soil was Pullman clay, a mixed thermic Torretic Pauleustoll”). For experiments using containers, state the texture of the soil material (e.g., “sandy loam” or “silty clay loam”). If uncertain about soil names or texture, consult a soil specialist at your institution or check the soil survey map of the country where the experiment was conducted.

For details on soil terminology, consult the *Glossary of Soil Science Terms* (Soil Science Society of America, 1984), which contains a basic list of 1200 terms, plus appendixes covering obsolete terms, tillage terminology, and new designations for soil horizons and layers.

**Statistical Reporting**

A report that involves the collection of experimental data should include an appropriate statistical analysis to aid the author and the reader in the interpretation of the results. Include sufficient summary data to enable the reader to interpret the statistical analysis. Give a complete description of the experimental design in the Materials and Methods section, as well as the treatments used and the statistical analyses performed. An explanation as to why a particular set of treatments was
chosen in light of the objectives of the experiment may be advisable in some cases. Also, in the Materials and Methods section, the statistical software package(s), procedure(s), and option(s) used to analyze data should be included. Indicate the type of Sums of Squares used (sequential or partial) to test hypotheses. If a model has more than one source of error, then state which error term was used to determine significance of model terms.

Where multiple regression is used, including polynomial models, indicate the criteria used to select the most appropriate model and present the $P$ value and coefficient of determination for the best model. Indicate which terms were tested in the full model, including squared or cubed terms, indicator variables, and interaction terms. Many authors present $P$ values for the linear, quadratic, and cubic models, but do not indicate which model best fits the data. Because the author is the most qualified to select the best model, information for only the best model should be presented. Include information such as the $P$ value, coefficient of determination, and number of observations ($n$), to enable readers to evaluate the model. Use of polynomials beyond quadratic is discouraged, unless the additional inflection points can be justified.

Although asterisks and the abbreviation NS have long been used to indicate the level of significance in tables and figures, presenting the $P$ value is encouraged because it is much more informative and today most software packages can accurately calculate exact values.

When means within a column or row are separated with a multiple comparison, at the bottom of each column also include a $P$ value from the analysis of variance to indicate the level of significance for treatment differences.

Plant biologists often measure the same plant or plant part several times during the course of an experiment (plant height, trunk circumference, fruit diameter, etc.). In such cases repeated measures analysis may be most appropriate. Researchers not familiar with repeated measures analysis may want to consult with a statistician.

Whenever an unusual statistical procedure is used, the author should briefly describe why that procedure is superior to more commonly used procedures, and provide a reference for the procedure.

Whether or not a mean separation procedure is used, including an analysis of variance (ANOVA) table may be helpful to the reader. Use of ANOVA tables is considered desirable by some reviewers and associate editors. Such a table gives a clear picture of the structure of the experiment and the contribution of each source of variation to the total sum of squares. In addition, it provides the necessary variance estimates for determining the standard errors of means ($\text{se}$) and confidence intervals. In the interest of saving space, these tables need to contain only the sources of variation, the degrees of freedom, and the mean squares for each of
the response variables. Figures are often presented with means and SEs of the means. The SE of the mean only provides information about the variation around each mean and is not useful for comparing means. Because SE of the mean often tend to clutter a figure and provide limited information, presenting the pooled SE of the treatment difference (obtained from using the mean square error from the analysis of variance) is suggested. Standard error of means should be presented only where the author wishes to show the magnitude of variation around the means or that the variances are not homogenous.

If data are being transformed before analysis, then state the transformation that was used and the reasons for choosing it. Furthermore, clarify whether the means being reported are based on the raw data or are the correctly back-transformed weighted means derived from the transformed data.

Referencing of texts or papers from which the author obtained a particular statistical procedure is desirable when such a procedure is one not commonly found in most standard texts. A statistician consulted in the preparation of the manuscript may be recognized either as a coauthor or in a footnote, but do not then make any revisions in the statistical presentation without the knowledge of the statistician involved. Many problems in data analysis can be avoided by consulting a statistician before the experiment is set up. Data collected from experiments with incorrect or unconventional designs often cannot be analyzed statistically.

**Taxonomy and Nomenclature**

**COMMON NAMES**

Although generic names should be used whenever possible, many plants are known also by their vernacular (provincial or common) names. Common names are given in Roman type and are not capitalized, even though they may have been named after people or places (e.g., japanese maple, virginia pine, colorado potato beetle, brussels sprouts, douglas fir, bermudagrass, st. augustinegrass). A generic name used as a common name is neither italicized nor capitalized (e.g., *Camellia*, camellia or *Rhododendron*, rhododendron). Common names of well-known crops (apple, pear, rose, tomato, etc.) can be used—indeed, are often preferred—in titles of papers, except where their use is ambiguous (e.g., bean). If the common name is given in the title, the scientific name must be listed in the additional index words (without the authority) and in the abstract (with the authority).

For diseases caused by specific organisms, capitalize and italicize when referring to the organism *Phytophthora cinnamomi* or *Phytophthora* as a genus or *Verticillium aloratrum* or *Verticillum* as a genus on the second reference; however, “phytophthora root rot” or “verticillium wilt” (in Roman type) when referring to the disease.
Cultivars

Give the name of a cultivar in Roman type after the name of the species and set it off with single quotes (e.g., ‘Green Ice’ cucumber or *Cucumis melo* L. ‘Green Ice’) in the text, table headnotes, and figure captions. Do not use single quotation marks in the body of tables (especially under the heading “Cultivar”) or within figures, except where their absence leads to ambiguity. Regardless of the origin of the name of a cultivar, capitalize its initial letter (with rare exceptions, depending on requirements of a modern language). Do not use the word “cultivar” (or the abbreviation “cv.”) and single quotation marks at the same time.

Interspecific crosses

The name of an interspecific hybrid consists of the generic name followed by a single Latin epithet (“collective” epithet), the latter immediately preceded by the math × (multiplication sign) (e.g., *Fragaria ×ananassa* Duchesne, *Pelargonium ×hortorum* L.H. Bailey, or *Canna ×generalis* L.H. Bailey (note that the × is flush against the species name, with no space between). This format is prescribed by the *International Code of Botanical Nomenclature*.

Rootstock nomenclature

Use the full alphanumeric designations for a clone or cultivar in the abstract; e.g., ‘Malling 22’ or ‘Malling–Merton 112’, with the diminutive following in parentheses; e.g., (‘M.22’) or (‘MM.112’). Subsequent references may use the diminutive without parentheses. When several stocks of the same series appear in sequence, give the diminutive for each (e.g., ‘M.2’, ‘M.9’, and ‘M.27’). Clonal rootstocks are cultivars and should be set off by single quotation marks.

Seedling rootstocks usually are not cultivars and should not be set off by single quotation marks. Seedling rootstocks become clones when increased in number asexually, which usually follows a naming process, which then produces a cultivar.

When graft combinations are listed, separate the components by slashes with the scion listed first, interstock (if present) next, and rootstock last, with single quotation marks around each where appropriate (e.g., ‘Fairchild’/’Cleopatra’).

Scientific names

See also the ASHS website (www.ashs.org/resources/plant names) and Germplasm Resources Information Network (GRIN) web site (www.ars-grin.gov/npgs).

Give the full scientific names of plants, disease organisms, and insects, along with their authority (and, if important, the cultivar name). (NOTE: Effective July 2008, reporting authorities for genera and lesser taxonomic classifications is optional in JASHS.) Style of providing scientific and cultivar names should conform to *The New Royal Horticultural Society Dictionary of Gardening* [A. Huxley and M. Griffiths (eds.). 1992]. For scientific and common names of edible fruit crops, consult Magness et al. (1971). For citrus species and relatives, the authority to use is Swingle and Reece (1967); see especially Swingle’s system (p. 358–363, 368–406) and Tanaka’s system.
(Table 3-3, p. 364–367). Many species’ names in the citrus literature are actually synonyms of those listed in these two systems; refer to these synonyms to get appropriate species or to give a reference for the epithet used.

The basic groups, categories, or taxa (singular, taxon), in descending order, are division, class, order, family, genus, and species. Treat the scientific names of all taxa as Latin, regardless of their derivation. Names of genera and higher ranks may stand by themselves, but the scientific name of a species is a two-word (binary) combination, called a “binomial,” consisting of a generic name followed by a specific epithet—*Dianthus caryophyllus* L. Italicize the generic name and the specific epithet, but not the authority.

Capitalize the name of a genus or taxon of higher rank (phylum, order, class, family, or genus and abbreviation of the genus) and of the name or abbreviation of the authority, but not of a specific epithet, even if it is derived from the name of a person or place (e.g., use *Cephalotaxus harringtonia*, not *Cephalotaxus Harringtonia*). Give the names of taxa before the rank of genus in Roman type; they are always plural in form and, therefore, require a plural verb (e.g., “the Orchidaceae are…”). A generic name that is followed by a specific epithet must be spelled out the first time it is used in the text or at the beginning of a sentence; subsequently, the generic name may be abbreviated to a single letter.

Never abbreviate specific epithets. A specific epithet is part of the binomial and should not appear as a monomial except, perhaps, when used in a table devoted to a single genus. Specific epithets are always lowercase, regardless of the name’s origin.

The person who first published the scientific name for a species is its author. Include the authority (in Roman type) with the scientific name of any organism; it needs to appear only once in an article, preferably in the abstract. The authority should not appear in the additional index words. If the name of the organism is changed subsequently, place the name of the original author in parentheses, followed by the name of the author responsible for the change [e.g., *Prunus persica* (L.) Batsch]. Use brackets to set off parenthetical use of the name of an organism that has an authority enclosed in parentheses {e.g., “[Prunus persica (L.) Batsch]”}

Avoid hyphenation or line-splitting of plant names; if splitting is unavoidable, however, a guide to hyphenation may be found in Smeal (1979).

The following scientific names are preferred by ASHS to those from other sources:

* Carya illinoinensis* (Wangenh.) C. Koch  
pecan

* Lycopersicon esculentum* Mill.  
common tomato

* Malus ×sylvestris* (L.) Mill. var. 

* domestica* (Borkh.) Mansf.  
apple
**PROOF CORRECTION**

**Proofreading**

Authors will be asked to carefully proofread their page proofs. Accuracy in the proofreading stage is the responsibility of the author. This is the last time the author will see the article before it is published, so thoroughness is essential.

Page proofs are sent via e-mail as PDF files. Look for an email message from “Sheridan.com” with the manuscript number and “e-proof” in the subject line.

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**TRADE OR BRAND NAMES**

Trade or brand names are not permanent; try to refer to the generic form of what you are using (e.g., “We used a tissue to wipe the thermometer.” instead of “We used a Kleenex to wipe the thermometer.”). If you must use brand names,
avoid using them without clarification. In general, refer to trade or brand names only parenthetically with the active ingredient, chemical formula, purity, and diluent or solvent stated clearly in the text and emphasized in preference to the commercial product; also, include the name, city, and state/country of the company that produces the product. Capitalize the first letter of trade or brand names. Do not capitalize adjectives made from trade names (e.g., petri dish). Avoid use of trade names in titles. If using trade names is unavoidable, include a footnote that disclaims endorsement of similar products of like properties (this is mandatory in some agencies and institutions). Capitalization replaces the use of trademark symbols. ASHS does not use trademark symbols.

WORD USE

The following list contains words or terms commonly misused or misspelled, jargon to avoid, trade names, and ASHS conventions. For hyphenated words, see Hyphenation. For nomenclature, see Taxonomy.

**about** An adverb of “approximately” or “circa.” The approximate symbol (≈) should immediately precede Arabic numerals.

**aboveground** One word.

**accommodate** Note spelling.

**according to** A phrase reserved for documents and written opinions or procedures. Use “said” for conversations.

**affect** As a verb, to cause a change or to have an effect. Almost never used as a noun. Compare “effect.”

**afterward** Do not use “afterwards.”

**among** A preposition used in relating three or more things. Compare to “between.”

**and/or** A conjunction that indicates that two entities are to be considered together or individually. It is best to avoid the term (e.g., “apple, peaches, or both” is preferable to “apples and/or peaches”).

**Anjou** Use instead of d’Anjou.

**apex** Plural is “apices.”

**approximately** Use “about” or use the approximate symbol (≈) immediately before Arabic numerals.

**arcsin** One word. Note spelling.

**at this point in time, at the present time** Use “now.”

**between** 1) A preposition used in relating two things; however, the phrase “to examine the relationship between application rate and fruit set, seed number,
and acid” is correct. Compare “among.” 2) A preposition paired with “and”
when giving a range (e.g., between 8 and 10 mm.” The phrase “between 8 to
10 mm” is incorrect. Compare “from.”

budbreak One word.

budline One word.

by means of “By” or “with” is sufficient.

bypass One word (no hyphen).

cannot One word. Do not use “can not.”

cantaloupe Use “muskmelon.”

carefully A term that is not necessary when describing procedure. Most tech-
niques are performed “carefully” in research.

caus ed by Use “incited by” for a disease.

check Use “control.”

Clorox Capitalized trademark (note spelling). The generic term is “chlorine
bleach” or “5.25% sodium hypochlorite solution.” It is suggested that the
actual chemical dilution be given and the use of the trademark be avoided.

coldframe One word.

compare A verb followed by “to” when a similarity is stated or suggested, as in
“he compared Bailey to Washington” (i.e., one the father of horticulture, the
other the father of his country). “Compare” is followed by “with” when details
of dissimilarity are stated or suggested, as in “he compared Bailey with Dar-
win” (i.e., pointing out details in which the two scientists were dissimilar).

comprise To include or contain (e.g., “the series comprises six bimonthly is-
sues” but six issues do not “comprise” the volume). Avoid “comprised of.”

concentration One says “high or low concentration,” not “large or small con-
centration.” One says “various concentrations (5, 10, 15 mg·m–1), not “varying
concentrations.”

continual Going on in time without interruption.

continuous Going on in time or space without interruption.

control Use instead of “check.”

correlated A term to be restricted to use in statistics. Use “related” for
nonstatistical descriptions.

cultivar A cultivated variety. Use the term “cultivar.”

data Plural form of “datum.” When used in a collective sense, “data” takes a
plural verb(e.g., “the data from the experiment are presented in Table 4”).
One says “many data” or “few data,” not “much data” or “little data.”

daylight One word.

desicc ate Note spelling.

despite the fact that Use “although.”
determined Use when indicating that measurements were taken (e.g., “growth was determined by counting nodes”). See also “measured,” “compare,” and “recorded.”
dieback One word.
different from Preferred to “different than.”
disease Symptom of the destructive effects of one or more biotic agents.
disorder Symptom of an abiotic (physiological) disturbance; need not be preceded by the word “physiological.”
dissertation An extended, written treatment of a subject; specifically, one submitted for a doctorate. The term, however, now is reserved generally for a work that includes an exhaustive review of the literature. Compare “thesis.”
Douglas fir Capitalize. Do not hyphenate.
drip irrigation Do not hyphenate.
dry weight Do not use dry mass. Do not hyphenate except when used as a modifier (e.g., “the dry-weight figures in column 3”).
due to Not to be used automatically as a substitute for “because of.” The phrase “yields fell due to severe frost” is incorrect; the correct form is “the decrease in yield was due to severe frost.”
due to the fact that Use “because.”
Duncan’s multiple range test Only “Duncan’s” is capitalized.
Du Pont The company’s style is to capitalize the name as shown when it stands alone. The full name is E.I. du Pont de Nemours & Co.
each When “each” is the subject of a sentence, it takes a singular verb (e.g., “Each of the limbs was sprayed”).
Earth Capitalize when referring to the planet.
effect As an adverb, to bring about or to cause to come into being. As a noun, the result of an action. Compare “affect.”
either...or When singular and plural nouns are linked with the “either/or” combination, the verb follows the number of the closest noun (e.g., “either sulfur alone or its derivatives are recommended as mild mildewcides”). Do not use commas to set off a phrase beginning with “or” if it is preceded by “either.” Compare “neither/nor.”
endpoint One word.
end result Use “result.”
ensure To make certain or guarantee that a desired event occurs. Compare “insure.”
erlenmeyer flask Note spelling.
estimated Use when a phenomenon is not easily measured by a single criterion or when the process is not a direct measure of the phenomenon or object (e.g., “growth was estimated by measuring leaf area”). Include the basis or means of
the estimation.

far red Two words and lowercase.

federal Do not capitalize, unless part of an official name, such as “Federal Trade Commission.”

feel Avoid the term, unless sensory perceptions are relevant in describing certain qualities of a product.

fewer Use when dealing with specific numbers of units that can be counted individually. Antonym is “more.” Compare “less,” “lesser,” “small,” and “smaller.”

Fiberglas Capitalized trademark. The generic term is “fiberglass” or “glass fiber.” Note the spelling.

finalize Use “end.”

Fraser fir Capitalize. Do not hyphenate.

fresh Acceptable as a collective noun when referring to produce or flowers destined for fresh market.

collective noun when referring to produce or flowers destined for fresh market.

fresh weight Do not use fresh mass. Do not hyphenate except when used as a modifier (e.g., “the fresh-weight figures in column 2”).

from A preposition paired with “to” when giving a range (e.g., “from 8 to 10 mm”). The phrase “from 8–10 mm” is incorrect. Compare “between.”

fruit Acceptable as a collective noun when referring to one or more of the same species (e.g., “10 apple fruit were collected each week”). Use the plural when referring to two or more species, e.g., “lemon and orange are citrus fruits.”

fruit set Two words.

F test No hyphen, unless used as a modifier (e.g., “F-test results”).

Fusarium Capitalize and italicize when referring to the organism Fusarium oxysporum or Fusarium as a genus on the second reference; however, “fusarium rot” (in Roman type) when referring to the disease.

gauge Do not use “gage.”

germplasm One word.

greater Use when referring to quality, worth, or significance. Antonym is “lesser.” Compare “higher,” “more,” and “larger.”

groundcover One word.

groundwater One word.

half-life Hyphenated as noun or adjective. Plural is “half lives” (no hyphen).

held Use “kept” unless contained in hand (e.g., “apples were kept in storage”).

higher Use when referring to position, rank, order, scale, or yield. Antonym is “lower.” Compare “greater,” “more,” and “larger.”

honeybee One word.

hopefully Due to constant misuse of this word, it is preferable to delete it completely. Proper use is “he hopefully anticipated the outcome.” It should not be
used as a substitute for “We hope” or for “it is to be hoped.”

**horticulturist** Do not use “horticulturalist.”

**illinoensis** Do not use illinoensis.

-ic, -cal Suffix endings used in adjectives. The “-ic” form is preferred, although the two endings sometimes convey different meanings (e.g., “economic botany,” but “economical process”).

**impact** Not a verb. Use “affect.”

**imply** To intimate or suggest a meaning not expressed or a conclusion to be drawn from allusion or reference, in contrast to a direct statement. Compare “infer.”

**incited by** Use instead of “caused by” for a disease.

**index** Plural is “indices” for measurable quantities, but “indexes” for a book.

**infer** To derive by reasoning; to declare or to conclude from facts or premises. Compare “imply.”

**infrared** One word.

**initiate** Use “begin” or “start.”

**in order to** Use “to.”

**input** An overworked word. Confine usage to computers or crops.

**in situ** Do not italicize.

**insure** To assure against loss; to take out insurance. Compare “ensure.”

**interaction** A term often used physiologically—and ambiguously. Reserve use of the term in its statistical sense for two effects that are not parallel in terms of the responses evoked.

**in vitro** Do not italicize.

**in vivo** Do not italicize.

**it is suggested that** Use “I (we) suggest.”

**kiwifruit** One word.

**Kjeldahl** Note spelling and capitalization.

**larger** Use when referring to dimension or size. Antonym is “smaller.” Compare “greater,” “higher,” and “more.”

**less** Use when dealing with amounts in a collective sense (time or distance). Antonym is “more.” Compare “fewer,” “lesser,” “lower,” and “smaller.”

**lesser** Use when referring to quality, worth, or significance. Antonym is “greater.” Compare “less,” “fewer,” “lower,” and “smaller.”

**LI-COR** Hyphenated and all uppercase.

**lima bean** Do not capitalize.

**lower** Use when referring to position, rank, order, scale, or yield. Antonym is “higher.” Compare “fewer,” “less,” “lesser,” and “smaller.”

**magnitude** See “order of magnitude.”

**Mason jar** Capitalize.
measured Use when indicating that measurements were taken by an instrument or scale (e.g., “length was measured by using a meter stick”). See also “determined.” Compare “recorded.”
media Plural of medium; do not use in the singular.
microphotograph A photograph on a greatly reduced scale, as on microfilm. Compare “photomicrograph.”
midpoint One word (no hyphen).
midseason One word.
modifying Use the term judiciously. “Modifying” effects are not necessarily “opposing” or in opposition to other effects.
molal Refers to molecular concentration per 1000 g of solvent.
molar Refers to molecular concentration per 1000 mL of solution.
more Use when dealing with a) specific numbers or units that can be counted individually (antonym is “fewer”) or b) amounts in a counted sense, such as time or distance (antonym is “less”). Compare “higher,” “greater,” and “larger.”
muskmelon Preferred term for “cantaloupe.” For specific types, use “netted muskmelons,” “‘Honey Dew’ muskmelons,” etc.
needless to say Leave out and consider leaving out whatever follows it.
neither...nor See “either...or.” “Neither” should be followed by “nor,” not by “or.”
number of, a Avoid this term. Use “several,” “many,” or “few.”
nylon Do not capitalize (no longer a trademark).
o’clock Do not use with abbreviations of time.
opposing See “modifying.”
order of magnitude Refers to a multiplication by a factor of 10.
order to, in Use “to.”
Osmocote Capitalized trademark. The generic term is “controlled-release fertilizer” or “slow-release fertilizer.”
overall One word (no hyphen).
parafilm Do not capitalize.
parameter A mathematical term. It should not be used as a substitute for “characteristic,” “attribute,” “feature,” or “quality.”
peat A generic term (for a mass of semicarbonized vegetative matter formed by partial decomposition of plant tissues in water, containing less than 10% sand or other matter and usually highly acid) that is used when the origin or source is unknown. “Peatmoss” or “moss peat” is of moss origin. “Sphagnum peat” is of sphagnum origin. “Reed-sedge peat” is of reed-sedge origin. Use “peat” except when the material is identified specifically.
peatmoss One word.
percent Noun, adjective, or adverb, spelled as one word. The symbol (%) and
not the term is used with numerals.

**percentage** A noun, indicating part of a whole expressed in hundredths, as in “percentage of leaf dry mass.” Often misused as an adjective (e.g., use “percent error” or “percentage of error,” not “percentage error”).

**petri dish/plate** Do not capitalize.

**phosphorous** An adjective. Resembling phosphorus, or used to designate a compound of phosphorus in which this element has a valance lower than that in phosphoric compounds.

**phosphorus** The element, as a noun. Sometimes used attributively, as in “phosphorus fertilizer.”

**photocopy** A generic term. Use instead of “Xerox.”

**photomicrograph** A photograph taken through a microscope. Compare “microphotograph.”

**Plexiglas** Capitalized trademark. The generic term is “synthetic glass” or “plexiglass.” Note the spelling.

**policymaking, policymaker** One word.

**pollinator** The agent of pollen transfer. Note spelling.

**pollinizer** The source of pollen. Note spelling.

**polymerase chain reaction** Spell out first mention, then abbreviate PCR.

**postharvest** One word.

**poststorage** One word.

**posttreatment** One word.

**preemergence** One word.

**preharvest** One word.

**prior to** Use “before.”

**Pyrex** Capitalized trademark. The generic term is “crack-resistant glassware.”

**quite** Do not use(e.g., the cultivar is “unique,” not “quite unique”).

**randomly amplified polymorphic DNA** Spell out first mention, then abbreviate RAPD. Do not use the plural (RAPDs), rather RAPD markers.

**rather** Do not use (e.g., the cultivar is “interesting,” not “rather interesting”).

**recorded** Use when gathering or posting data, with a writing or printing device, to make a record for future use (e.g., “the date was recorded on the leaf with indelible marker pen after the blade had expanded” or “temperature was recorded with a 7-d thermograph”). Compare “determined” and “measured.”

‘**Redchief Delicious**’ A cultivar; incorrectly written ‘Red Chief Delicious’.

**relatively** The term implies comparison and should accompany a basis for comparison: “relative” to what?

**replicate** Verb; “This test was replicated three times.”

**replication** Noun; “We used three replications.”

**restriction fragment-length polymorphism** Spell out first mention, then
abbreviate RFLP.

**ringspot**  One word.

**root ball, root rot, root zone**  Two words. Hyphenate when used as a modifier (e.g., root-zone temperature”).

**rowcover**  One word.

**runoff**  One word.

**Saran**  A trademark term for plastic products, such as “Saran Wrap” (a kind of plastic film) and “Saran Cloth” (a shadecloth).

**Scotch tape**  Use “cellophane tape.”

**seedcoat**  One word.

**separate**  Avoid this term as an adjective. In the phrase “the procedure was used in 12 separate trials,” the word “separate” adds nothing.

**shadecloth**  One word.

**shelf life**  Two words. Do not hyphenate.

**sidedressing**  One word (no hyphen).

**significant**  Confine use of the term to statistical judgment. Do not use the term loosely for “important,” “noteworthy,” “distinctive,” or “major.”

**smaller**  use when referring to dimension or size. Antonym is “larger.” Compare “fewer,” “less,” “lesser,” and “lower.”

**southernpea**  One word. Do not capitalize. “Cowpea” is the preferred term, but “southernpea” is acceptable for edible cultivars.

**sphagnum**  A moss that grows only in wet, acid areas (such as in ditches or along lake shores) where its remains become compacted to form peat and whose aerial portions are harvested and dried. Synonym: “sphagnum moss.” Do not use “sphagnum peatmoss.”

**sphagnum peat**  Partially decomposed sphagnum.

**stepwise**  One word (no hyphen).

**Student’s t test**  “Student” is the pseudonym for British statistician W.S. Gossett and is capitalized.

**Styrofoam**  Capitalized trademark. The generic term is “plastic foam.”

**subsequent to**  Use “after.”

**sulfur**  Preferred spelling of “sulphur.”

**sweetpotato**  One word.

**terminate**  Use “end.”

**that**  A relative pronoun introducing a restrictive (defining, limiting) clause. For example, in the sentence—“The tree that survived the treatment developed fruit.”—the defining clause (“that survived the treatment”) is needed to identify the tree being discussed. Compare “which.”

**thermos**  Do not capitalize (no longer a trademark) except when referring to the specific brand of vacuum bottle.
thesis  A dissertation written by a candidate for an academic degree. Do not use the term “PhD thesis.”
this  Do not use as a noun. After explaining a certain result, a sentence such as the following might appear: “This indicates an interaction of A with B.” This what? Determining what “this” means often is difficult in science. Use specific nouns (e.g., “This increase indicates…”).
toward  Do not use “towards.”
troubleshoot  One word.
t test  Lowercase and italicized t. Not hyphenated.
Tukey’s Studentized range test  Note capitalization.
turfgrass  One word.
ultraviolet  One word.
unaffected  Use instead of “not affected.”
uniconazole  Note spelling.
utilize  Use “use.”
variety  See “cultivar.” Use the term cultivar exclusively when referring to a cultivated variety.
versus  Spell out and do not capitalize in titles; otherwise, use “vs.” (including period).
vesicular–arbuscular  Use en-dash. Capitalize both words if used in a title.
Waller–Duncan  Use en-dash. Capitalize both words.
wastewater  One word.
wavelength  One word.
whether or not  Use “whether.”
which  A relative pronoun introducing a nonrestrictive (nondefining, descriptive) clause. For example, in the sentence—”The third tree, which survived the treatment, developed fruit.”—the nondefining clause (”which survived the treatment”) merely gives additional information about its subject, which has already been identified by the adjective “third.” Compare “that.”
winterhardiness  One word.
winter hardy  Two words, unless used as a modifier (e.g., “winter-hardy plant.”)
worldwide  One word.
Xerox  Capitalized trademark. The generic term is the noun “photo copy.” Do not use as a verb.
X-ray  An acceptable jargon noun for “X-ray photograph” or “X-ray picture.” Adjective and verb are “X-ray.”