Title

The AusTraits Plant Dictionary

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Abstract

Traits with intuitive names, a clear scope and explicit description are essential for all trait databases. Reanalysis of data from a single database, or analyses that integrate data across multiple databases, can only occur if researchers are confident the trait concepts are consistent within and across sources. The lack of a unified, comprehensive resource for plant trait definitions has previously limited the utility of trait databases. Here we describe the AusTraits Plant Dictionary (APD), which extends the trait definitions included in the new trait database AusTraits. The development process of the APD included three steps: review and formalisation of the scope of each trait and the accompanying trait description; addition of trait meta-data; and publication in both human and machine-readable forms. Trait definitions include keywords, references and links to related trait concepts in other databases, and the traits are grouped into a hierarchy for easy searching. As well as improving the usability of AusTraits, the Dictionary will foster the integration of trait data across global and regional plant trait databases.

Background & Summary

Large-scale analyses of trait data are now commonplace across many scientific disciplines, from vegetation modelling, to evolutionary dynamics and conservation planning [1,2]. At the broadest level, a trait is any morphological, physiological, chemical, or life history feature of an organism that can be documented [3]. Traits capture the enormous heterogeneity in form and function across individuals, populations, or taxonomic units. Variation in trait values reflects the ecological and evolutionary processes that give rise to functional diversity and, in turn, is thus used to define and describe units of biodiversity (e.g., species) [4]. For vascular plants, the increasing integration of big trait datasets into studies of plant ecology and evolution can be attributed to the rapid growth in databases that collate and/or harmonise collections of field-based observations for re-use [5]. Some plant trait databases are global [6–8], while others have regional [9–12] or taxonomic [13] scopes. Some target specific organs or functions [14], and others are more general, such as floras aimed at plant identification [15]. Combined with the growing interest in plant traits, the surge in available data is expanding our ability to answer a wide range of questions about the global flora [6,16].

Usefully and accurately capturing the wonderful diversity of plant form and function to address ecological, biogeographic and evolutionary questions involves the non-trivial challenge of reconciling many and often conflicting definitions of plant traits. Garnier[17] wrote of the “semantic bazaar” in trait ecology, referring to the diversity of possible meanings for a single trait name. For instance, does plant height refer to vegetative height or the height of the highest inflorescence, the height of a typical adult or that of the tallest individual? Is leaf length the length of the leaf blade or does it include petiole length? Without definitions, data cannot be easily reused or merged across trait databases, as the trait names by themselves might not clearly indicate the “trait concept” [5]. Moreover, as each researcher sees the diversity of form and function in the natural world through a unique lens, the same physical feature on the same plant may be scored as being part of different trait concepts or given a different value of the same trait (Figure 1).

Ideally, the relationships between different phenotypes and terms would be standardised, allowing researchers to easily reuse data in new contexts. Just as a taxon concept can be described as “a circumscribed set of organisms” (https://github.com/tdwg/tnc/issues/1), a trait concept delimits a collection of trait values pertaining to a distinct characteristic of a specific part of an organism (cell, tissue, organ, or whole organism). Trait names, like taxon names, are associated with each concept, attaching a reusable, interpretable label to each concept, but like taxon names require common terminology across research groups.

Currently, research is hindered by the lack of explicit definitions outlining what trait concept a particular trait name refers to, what measurements a specific trait concept encompasses, and the difficulty of reconciling many plausible terms for a single phenotype.

As efforts towards data compilation and database integration have progressed, the need for explicit definitions is increasingly being recognised. Explicit, widely-adopted schemes have long existed for just a few traits (e.g. Raunkiaer's life forms)[17] and plant morphology books have long offered a rich vocabulary to describe plant parts [18,19]. Meanwhile, trait handbooks have emerged in the ecology and evolutionary biology literature as tools for standardising measurements and terminology [21–26]. Individual trait databases are also increasingly incorporating explicit trait definitions, enumerating allowable categorical trait values and linking their trait definitions to trait handbooks or published trait ontologies (Table 1)[7,10,17,27–29]. The Thesaurus Of Plant Characteristics (TOP; https://top-thesaurus.org/)[17] was an initiative to define trait concepts for traits in the TRY plant trait database (Table 1) [6]. Still a work in progress, it was the first extensive effort to publish ecological plant trait definitions that included expected units, allowable categorical trait values and references. There also exist more formal vocabularies put forward by the Open Biological and Biomedical Ontology Foundry (OBO; https://obofoundry.org). One of the OBO Foundry ontologies, the Plant Trait Ontology (PTO; https://bioportal.bioontology.org/ontologies/PTO; Table 1) [30], was the first extensive formal ontology of plant traits to be published, including definitions for hundreds of traits relevant to agricultural research organised into an intuitive hierarchy. EnvThes likewise offers a formally published ontology to support Long Term Ecological Research (LTER) data (https://vocabs.lter-europe.net/envthes/; Table 1) [32] and is focused on ecological traits. All these pioneering assemblies of trait definitions have advanced global integration of plant trait definitions, but these works remain incomplete relative to the breadth of trait concepts captured by large trait databases.

Meanwhile, the core components that must be encapsulated to fully define a trait concept have been established by emerging standards in bioinformatic platforms. They include the trait's name (label), a concise but explicit description, standard units (for numeric traits) and allowable range (for numeric traits) or literal values (for categorical traits) [29,32–34]. Additional fields to enhance trait findability include keywords and a trait hierarchy. Interoperability and reusability are increased by including references and links to identical or similar traits in other trait databases. A further step toward making trait definitions FAIR (Findable, Accessible, Interoperable, Reproducible)[35] is to explicitly link each trait name to a published trait definition [29] and to publish a machine-readable trait ontology that accompanies a database or research project.

Despite these multiple efforts from multiple groups, the research community currently lacks comprehensive compilations of definitions that can be readily applied to new data. The existing trait dictionaries, thesauri, and ontologies (Table 1) document an insufficient breadth of traits or offer only partial trait definitions, omitting information such as defined allowable categorical trait values and preferred units, limiting their reuse. For example, we could not find an existing dictionary that contained a definition for a sufficient diversity of traits, with enough detail, or in machine readable format, to support usage of the new AusTraits database. AusTraits is a large continental plant trait database, that currently includes more than 1.25 million data records (v4.1.0) spanning more than 500 traits and nearly all of Australia's 26,000 plant species [11]. It includes data for a broad selection of traits including those related to plant morphology, fire ecology, life history, plant physiology, and nutrient contents. The AusTraits workflow requires each trait concept to be linked to allowable trait values, allowable ranges, and accepted units. As the project could not reuse an existing resource, AusTraits developed its own trait dictionary, which is available on the project's GitHub repository (https://github.com/traitecoevo/austraits.build) and as a data

object embedded within the trait database (Figure 2). The traits initially had informal definitions, developed by the AusTraits team, which referenced published trait handbooks, other reference books or an existing thesaurus or glossary, if available, or else were developed in conversation with researchers who contributed data for a unique trait to the database. This process allowed the database to expand rapidly and efficiently, without being limited by availability of dictionaries, whilst still documenting trait definitions, preferred units, numeric ranges and allowable categorical trait values for all traits in the database. While these definitions have allowed AusTraits users to accurately interpret all data within the database and to manually link AusTraits data to those in other trait databases, it was apparent that the utility of AusTraits would be further enhanced by harmonising trait definitions through a formal vocabulary.

In this paper, we present the AusTraits Plant Dictionary (APD). This comprehensive reference for trait data in AusTraits is also a contribution intended to further integrate global plant trait databases. The APD expands the original AusTraits trait definitions into a formally published dictionary that spans the breadth of trait data included in the database. Most of these definitions will be useful in a global context and expand what is available in existing resources. We used a rigorous review process to refine trait descriptions, added additional metadata to each definition and released the trait dictionary in both a human-friendly and a machine-readable format. Our goal was to progress the global integration of plant trait data in two key ways: first, to create a resource that allowed all data within AusTraits to be effectively mapped onto semantically distinct trait concepts, enhancing the usability of AusTraits; and second, to link this information to other trait databases, thesauri, ontologies and trait handbooks, to both allow the reuse of the APD definitions and facilitate analysis of AusTraits data in combination with data from other databases.

The APD takes the plant trait ecology research community closer to having a global trait dictionary. In addition to supporting AusTraits, we hope that our approach of reviewing and reconciling the often-conflicting trait concepts and descriptions and making them FAIR means we have built a resource that can be reused and built upon by other research initiatives in a global context. Currently, trait concepts and categorical trait values are mostly restricted to traits and terms required to map AusTraits data, but we expect the dictionary to expand over time to support traits and trait values present in other trait databases. For instance, the APD currently has only sparse coverage of root traits, completely lacks traits pertaining to tissue decomposition rates, and is missing some key traits in the hydraulics literature. While a first version of the APD is now available, we expect to continually build upon the dictionary on the project's GitHub portal, offering successive releases. A customised GitHub issue template allows researchers from across the plant trait research community to suggest additional traits to add to this initiative. A submission would include a proposed trait concept to add, a trait label and description, allowable ranges or values, and references. Once reviewed by the AusTraits team these trait concepts could be included in future releases.

Methods

There were three components to building a dictionary for these traits. First, we reviewed and revised each trait concept, minimising ambiguity in its scope and writing an explicit, yet concise trait description. Second, we added metadata fields to each trait definition. Third, we compiled all trait concepts into a single resource, output simultaneously in both human and machine-readable formats.

Reviewing and revising trait concepts, an overview

Preliminary review. Through a preliminary review we divided all traits into three groups: 1) trait concepts that were clear and simple and could be reviewed by just the core AusTraits team; 2) trait concepts that required a brief review by experts; and 3) trait concepts where the trait's scope or allowable values required significant discussion amongst experts; these were reviewed in a series of workshops (Table 2). For the 149 traits that were the content of an element, isotope, metabolite, or other biochemical compound in a specific plant organ, tissue or cell, the meaning and scope of the trait was usually unambiguous and universally agreed upon; few of these traits required a review outside the core AusTraits team. A review by just the core AusTraits team was also sufficient for 134 additional traits with very explicit, simple definitions, or that were trait concepts linked directly to a publication and accompanying dataset.

Expert reviews. 116 physiological and floral traits were reviewed by experts with extensive experience. These reviewers were able to efficiently identify unrealistic allowable value ranges, nonstandard units, incomplete trait descriptions and call attention to missing or inappropriate key references.

Workshop reviews. 112 traits were allocated to a specialist workshop, generally because they contained long lists of synonymous or poorly defined categorical trait values or were traits measured differently by different groups of researchers. For traits that required an extensive review, we used a series of small (5–10 person) workshops that brought together researchers who would ideally apply an identical trait concept to diverse research situations. The workshops included researchers at government agencies, universities or herbaria; researchers who were functional ecologists, taxonomists or systematists; and researchers with expertise in diverse plant communities. Three workshops were conducted covering traits within the realms of 'Seed and dispersal traits' (October 2021), 'Leaf and whole plant vegetative traits' (August 2022) and 'Fire response and regeneration traits' (May 2023); each was comprised of 4 or 5 two-hour workshop sessions. Moderated by AusTraits team members, each session was dedicated to clarifying the trait concepts, refining the trait descriptions, identifying key references and carefully compiling a list of allowable trait values that was succinct and distinct. The trait workshops identified trait concepts that were too vague, trait concepts that lacked semantic clarity and curated categorical trait values.

Completing trait definitions

The core goal of all reviews was to delineate trait concepts and lists of trait values to which all data submitted to AusTraits could be unambiguously mapped. The outcomes of the workshops, expert reviews and internal reviews were used to write a trait description and propagate additional metadata for each trait concept.

Trait descriptions and comments. A clear, explicit and comprehensive trait description was drafted for each trait. Whenever possible, trait descriptions were closely aligned to those in trait handbooks, reference books, research papers describing key methods and existing trait ontologies. Following the example set by formal ontologies (e.g. the OBO Foundry ontologies PATO, PO and PTO) and the TOP Thesaurus, a second formal description was drafted for each trait where all technical terms were linked to classes (words; concepts) in published ontologies. This removed ambiguity in what was meant by a term and required that all definitions were written with reference to a narrow list of words. Although this formal method generated a unique definition for each trait, the less formal, non-annotated trait descriptions were considered essential to convey the trait concepts to users, as the encoded descriptions are often awkward to read and interpret. In addition, a comments field provided a location to document notes, including referencing similar traits, best practice measurement methods, important context variables and possible sources of error within the

amalgamated data. For instance, the definition for the trait "leaf area" could include a comment indicating that although only leaf area data are meant to be mapped to this trait concept, many authors will merge leaflet and leaf area data under the title "leaf area" and therefore trait databases, such that AusTraits, will contain a mix of leaf and leaflet area data under the "leaf area" trait. Meanwhile, for photosynthetic rate traits the comments field could indicate that it is best practise to document leaf temperature as a context property.

In addition to the trait description and comments, descriptive metadata fields were added to each trait concept (Table 3) [36]. The metadata fields include those required for data processing (e.g. allowable ranges and allowable trait values), those that increase trait concept findability (e.g. keywords), those that properly document the source and scope of the trait (e.g. references, reviewers) and those that increase trait concept interoperability across datasets (e.g. matches to other databases).

Metadata required for processing. The R pipeline that compiles AusTraits requires five pieces of information for each trait concept: the label (i.e., a trait name), the trait type (numeric versus categorical), the allowable range of values for numeric traits, the standardised units for numeric traits, and the allowable trait values for categorical traits (Figure 2; Table 3).

Metadata to increase trait concept findability. Metadata should also include descriptors that aid in the discovery of the resource, here the individual trait concepts. In addition to offering a trait hierarchy, APD includes three fields to increase trait findability: the plant structure being measured (e.g., stem, leaf, root, whole plant, flower), the characteristic being measured (e.g., mass, shape, force) and additional keywords (Table 3).

Metadata to increase trait concept documentation. Each trait in the APD includes metadata to record the date trait concepts were described and revised; the people involved in reviewing each trait concept and trait definition; its applicability (i.e., scope; the trait might only be scorable for specific taxonomic groups or in plants that have leaves); and past labels (names) used for the identical trait concept. In addition, references were linked to traits whenever possible; these included trait handbooks describing the trait, manuscripts introducing or championing the trait and review papers noting the best traits to measure to document a particular plant function. Two fields link the standardised units to published vocabularies, described below.

Metadata to increase trait concept interoperability. A cluster of metadata elements promote the interoperability of this resource with other databases by documenting trait concepts in other trait databases or ontologies that are identical, similar, or related to a specific trait concept in the APD (Table 3). Trait concepts from TRY [6], TOP [17], GIFT [7], LEDA [27], BIEN [8], BROT 2.0 [10], the Palm Traits Database [13], the Plant Trait Ontology [30] and EnvThes [31] were cross-mapped to trait concepts in the APD.

Mapping metadata fields to concepts in published vocabularies. In a standard tabular format, the metadata fields would be the column headers, each specifying a different piece of information documented about the trait. In a formal ontology, each metadata field included in the APD must be matched to an appropriate annotation property. These are published, formally defined terms for `label`, `description`, etc. (Table 3). By preference, metadata fields are linked to concepts defined by the often-used Simple Knowledge Organization System (SKOS; https://www.w3.org/TR/skos-primer/)[37], Resource Description Framework (RDF; https://www.w3.org/TR//rdf11-primer/)[38], or dcterms (Dublin Core Metadata Initiative) [39] vocabularies. Properties defined by the Ecological Trait-data Standard (ETS) [32] were also reused; this schema is establishing itself as a well-designed ecological trait database structure. Units were aligned to the Unified Code for Units of Measure (UCUM; https://ucum.org/ucum) standard with specific machine-readable representations of each

unit downloaded from the Units of Measurement (UOM) portal (https://units-of-measurement.org/). The UCUM standard follows clear, simple rules, but also has a flexible syntax for documenting notes that are recorded as part of the 'unit' for specific traits, yet are not formally units, in curly brackets [40]. For instance, {count}/mm2 or umol{CO2}/m2/s, where the actual units are 1/mm2 and umol/m2/s. An added advantage is that the UOM representations include links to identical units in a collection of other published ontologies. Properties not present in any of these ontologies were mapped to ones in the Semantic Science Information Ontology (SIO) [41], the Extensible Observation Ontology (OBOE) [42], Datacite [43] and the iAdopt Ontology [44] (Table 3).

Within each APD trait concept, some trait metadata fields were simply text strings (i.e., trait description), while other metadata values were themselves published concepts with a Uniform Resource Identifier (URI) (an inclusive term, that encompasses both URLs and Internationalized Resource Identifiers [IRIs]). For instance, references mostly have a DOI (digital object identifier), reviewers were identified by their ORCID numbers (Open Researcher and Contributor Identifier) and keywords were all identified by their URI's from various published ontologies.

Trait hierarchy

For ease of grouping trait concepts, we established a trait hierarchy into which the traits could be slotted. At the highest level, all traits within the APD could be divided into four categories: biochemical traits, morphological traits, physiological traits and life history traits (Table S1). Three of these were exact matches to classes defined by the Plant Trait Ontology (plant biochemical trait (http://purl.obolibrary.org/obo/PTO_0000277); plant morphology trait (http://purl.obolibrary.org/obo/PTO_0000017); and biological process trait, physiological process trait (http://purl.obolibrary.org/obo/PTO_0000283)), while life history trait was defined within APD. Additional hierarchical levels were established, again using a combination of terms from the Plant Trait Ontology and ones defined within APD (Table S1). The trait hierarchy was mapped into the formal ontology as nested SubClasses, cascading down from the top concept, a Plant Trait (http://purl.obolibrary.org/obo/PTO_0000000).

Building APD into a machine-readable resource

The primary output for the trait concepts and their associated metadata needed to be in a machine-readable format that could both be stored on the project's GitHub repository and published online through the Australian Research Data Common's (ARDC) Research Vocabularies Australia (https://ardc.edu.au/services/research-vocabularies-australia/). Each term defined within the APD requires a unique and stable URI. This includes not just the trait concepts, but also the allowable categorical trait values, the trait groupings within the trait hierarchy, and the selection of terms within a glossary. Although the APD outputs are archived on the project's GitHub repository, we chose to register the APD namespace with the URI redirection service w3id.org to ensure the permanency of the URI's even if our project repository were to be moved. The trait concepts, trait groupings for the hierarchy, and allowable categorical trait values are within one schema, w3id.org/APD/traits/ while the glossary terms are in a second schema, w3id.org/APD/glossary.

A machine-readable representation was built using an R script that first merged seven separate data tables into a single table formatted as RDF Triples, the core unit of the Resource Description Framework (RDF) data model. With the triples format, all information content is collapsed into a single long-format document with three columns, the subject, the predicate, and the object. The subject is always the URI for a concept or term, and, for the APD, included both the URI's within the w3id.org/APD namespace as well as concepts within the ancillary tables, such as ORCIDs for reviewers, DOI's for references, or URI's for concepts

reused from published vocabularies. The predicate indicates a property of the object that can be described. The predicates in AusTraits are the annotation properties in Table 3 and additional terms specified under `Column` in Tables S2-S10. Each predicate is also a URI. The object is the value for the specific predicate for the specific object.

Spreadsheets with data that were converted to triples include: 1) the core trait concepts and their metadata; 2) trait references; 3) trait reviewers (by ORCID); 4) classes from published ontologies; 5) terms from the Units of Measurement Ontology; 6) allowable categorical trait values; 7) the trait hierarchy under which the traits in the APD could be grouped. Terms sourced from published ontologies or other sources were mapped into APD as their own entities to ensure their labels and descriptions were included within APD, rather than simply being identified by an URI. As each value of a property of an object is in a new row in triples format, there may be more than 30 rows of data for a single trait concept (Table S2), and, in total, there are more than 33,000 rows of unique object-predicate-value combinations within the APD.

The R package rdflib [45] was used to serialise the table of triples into RDF objects, output in Turtle (APD.ttl), N-Triple (APD.nt), N-Quad (APD.nq) and JSON Linked Data (APD.json) formats.

The RDF serialisations were complemented by two derivatives, created from the N-Triple output using a combination of R and Quarto scripts (Figure 4). The first is a HTML landing page for human interaction with the machine-readable formats (https://traitecoevo.github.io/APD/index.html) to which all searches for individual concept URIs are automatically redirected. And second is the YAML (.yml) file required by the AusTraits workflow to compile the database. It includes only the trait labels, trait description, type, allowable range, allowable trait values and required units and is located within the austraits.build GitHub repository (https://github.com/traitecoevo/austraits.build). The YAML format offers a flexible data serialisation format to capture diverse metadata in a single file, as it has a nested format which allows different numbers of levels beneath each header. This permits both easy data input and human interpretation.

Data Records

Trait concepts and allowable trait values

In total, APD includes 515 traits, including 112 categorical traits and 403 numeric traits (Table S3). These vary from well-known traits like leaf area to bespoke ones like leaf pendulousness that are measured only for specific research questions. The internal reviews, expert reviews and reviews through the trait workshops all worked toward clarifying trait concepts and developing clear trait descriptions and appropriate lists of allowable categorical trait values.

Trait concept, label and description too vague. The vocabulary workshops uncovered several instances where trait names were ambiguous and may have led to the misinterpretation of data. For instance, the trait 'leaf angle' was defined as the angle between the stem and the leaf blade, but it was identified that the data in AusTraits referred to the leaf blade's angle relative to the solar zenith. There are now two traits in the APD with more explicit labels and definitions, leaf axil angle and leaf inclination angle. Another example of a semantically unclear trait label was the trait capturing the hairiness of juvenile leaves. It was unclear if these were the leaves on a juvenile plant or the juvenile (regrowth) leaves on an adult plant following disturbance. Again, it was necessary to adopt two separate traits whose scopes were more explicit. In addition, by linking the terms in the trait description to ontologies, it was possible to clearly distinguish between a leaf on a 'juvenile

plant' (https://purl.obolibrary.org/obo/PATO_0001190) versus a 'juvenile leaf' (https://purl.obolibrary.org/obo/PO_0006339) on an adult plant.

Trait concept too broad. There were several traits that were identified as being too broad and including two (or more) semantically distinct concepts; these traits were split into multiple traits with a narrower, explicitly defined scope. For instance, fruit type included both true, botanical fruit types and terms that simply indicated whether a dispersal unit was dry or fleshy. The data initially merged together under fruit type were split into a trait that captured true botanical fruit types, such as achenes and drupes [46] and then two traits that indicated specific functions of the fruit, independent of its formal classification, i.e., fruit fleshiness and fruit dehiscence. Plant growth form included terms that pertained not only to the actual entire plant form, but also values indicating whether it was terrestrial, aquatic, or epiphytic and whether it was a parasite. The initial scope of data mapped to plant growth form was divided into a simpler plant growth form which was focused on the plant's perennating 3-dimensional shape, with ancillary information mapped to plant growth substrate, plant succulence and, in part, a revised stem growth habit and parasitic traits (Figure 3). Trait concepts that are too broad are a global problem and other trait databases have also recently taken the approach of splitting plant growth form into more tractable traits with a clearly defined 'entity' and scope [7,47]. For the APD, this allowed a considerable reduction in repetitive trait values, such as remapping 'aquatic_herbs'; 'aquatic_shrubs' and 'aquatic_trees' to 'herbs', 'shrubs' and 'trees' under plant growth form and as 'aquatic' under plant growth substrate.

Curating categorical trait values Certain categorical traits were identified as those most requiring standardisation of trait values and were selected to review during the workshops. These included seed shape, fruit type, dispersal syndrome, leaf shape, leaf type and plant growth form. These were traits for which there were data in many datasets, but which lacked universally agreed upon allowable trait values. Despite attempts to condense terms and align meanings, AusTraits had 50–80 trait values for leaf shape; many were clearly synonymous terms or terms not actually related to the shape of the leaf blade. There were two core reasons for these long lists of terms: 1) traits that integrated data from both the ecology and the systematics communities, with different researchers favouring different sets of terms; and 2) the lack of available vocabulary to describe particular trait phenotypes.

Plant morphologists and taxonomists are equipped with botanical glossaries[19,20,48,49], offering a detailed vocabulary to describe all nuances of a plant's morphology. In contrast, while ecologists use these morphological terms when appropriate, ecology datasets also include terms that capture specific functional roles, often using a merging of formal and informal terms. By curating categorical trait values, two core revisions were made. The first was to condense the extensive list of terms in botanical glossaries. Although many researchers in these fields take advantage of this rich descriptive vocabulary, they were amenable to reducing the list of terms allowed as values for a given trait, realising that the fine-grained distinctions were unlikely to have functional significance, but also that many terms were so similar they were unlikely to be used consistently, even by the experts. This concurs with recent research that suggests that all people, even expert botanists, were more likely to correctly identify a plant's character when there were fewer options to choose from [50]. Synonymous terms were listed within the description of each trait value (Table 3), clarifying the scope of each trait value retained and facilitating searches for terms that were omitted. For example, for seed surface texture, the final list included 11 trait values, but an additional 28 terms were mapped as synonyms (Table 4). For some traits, appropriate lists of terms were discovered through literature searches or emerged through workshop discussions. For instance, the many leaf shape values could easily be mapped to the terms in a resource

established by the Systematics Association Committee 60 years ago[51], which was not known to most but familiar to one workshop participant.

Some challenges emerged when selecting a list of allowable words to describe the ecological or functional trait values where no succinct, unified list of terms exists. The difficulty is exemplified by plant growth form, where even successive versions of the same trait handbook presented barely overlapping lists of allowable growth form terms[21,22], despite this being one of the most recorded traits worldwide. These resources and many others share the use of 'tree', 'shrub' and 'herb', but beyond these terms resources diverge in their list of allowable plant growth form values. Our list uses terms from both of these references as well as many others [7,17,47], compiling a list onto which all existing AusTraits data could be mapped. Our goal was to balance having enough terms to capture morphological and functional diversity, while allowing for comparative analyses across groupings. For plant growth form, as for other traits, this list included terms of ecological or descriptive significance that might be used only for specific taxa or ecological situations, yet were required for trait measurements in those circumstances. For the Australian flora, terms like 'mallee' and 'hummock' were deemed essential to describe distinct plant growth forms, although these terms are absent or rarely used globally. In the final list there was a clear scope and description attached to each trait value.

Data files

The APD GitHub repository (https://github.com/traitecoevo/APD) includes the eleven spreadsheets required to compile the final resource.

APD_traits.csv is the core data table, which includes trait labels, trait descriptions and all associated metadata for each trait concept (Table S4). As indicated in Table 3, some columns are textual strings, others are numeric and some refer to pre-existing entities (concepts, classes). The pre-existing entities are documented in an additional four data tables, APD_references.csv, APD_reviewers.csv, APD_units.csv and published_classes.csv.

APD_references.csv links each reference indicated in APD_traits.csv to its DOI (or alternative identifier), also providing a title and complete reference (as a string) (Table S5).

APD_reviewers.csv links each reviewer indicated in APD_traits.csv to their ORCID number (Table S6).

APD_units.csv links the standardised units indicated in APD_traits.csv to their respective URLs in the Units of Measurement Ontology (Table S7). The data table includes a description of the unit, links to its SI and UCUM representation and indicates other ontologies with definitions for this unit.

published_classes.csv documents terms from published ontologies used as keywords, measured characteristics, measured structures, or to describe the trait type. The label, description, IRI, scheme URI and scheme prefix are provided for each term (Table S8).

APD_categorical_values.csv contains the allowable trait values for each categorical trait, including descriptions of each term and indicating the trait concept to which the term is linked (Table S9).

A challenge in the compilation of APD was that ontologies allow only a single instance of each word to be used, with a single definition. While each trait name is unique, the same term (word) can be used as a categorical trait value for multiple traits with subtly different meanings and possibly different meanings to a pre-existing ontology. Generalising the definitions to be applicable to all instances of its use would mean that its definition would be

far broader than implied as a specific trait value for a single categorical trait. The solution for APD was for official trait values to be the merging of the trait label and the term, while the label for the term could be a simple word that might be reused. For instance, the trait value *hairy* is used for five separate traits and for the trait *Juvenile phase leaf hairiness* the formal trait value becomes *leaf_hairs_juvenile_leaves_hairy*.

APD_trait_hierarchy.csv indicates the hierarchical structure into which the trait concepts are mapped (Table S10).

APD_glossary.csv includes a collection of terms used repeatedly within APD trait concept descriptions or as keywords, but which lacked an appropriate published definition (Table S11).

APD_annotation_properties.csv indicates the source, label and description for each of the annotation properties (Table 3) used to capture metadata for the trait concept s (Table S12).

APD_namespace_declaration.csv indicates the URI for each vocabulary prefix referenced in APD_traits.csv and serves as the namespace declaration when compiling the RDF representation (Table S13).

APD_resource.csv is already in Triples format and includes annotation properties about the core APD resources, APD/traits and APD/glossary (Table S14).

Access

The data are available under a CC-BY 4.0 license, allowing reuse with attribution. The versioned releases are archived on Zenodo (https://doi.org/10.5281/zenodo.8040789). The version controlled machine-readable Turtle representation is also published through Research Vocabularies Australia, part of the national research infrastructure operated by the Australian Research Data Commons (ARDC) (https://vocabs.ardc.edu.au/viewById/649). The APD GitHub repository (https://github.com/traitecoevo/APD) has both versioned releases and ongoing development versions. The APD namespace (w3id.org/APD) and trait concept URI's (e.g. https://w3id.org/APD/traits/trait_0000014) also redirect to the versioned releases on the APD GitHub repository.

Technical Validation

The APD.ttl file (Turtle serialisation) was run through a skos validator to confirm that all relationships were consistent, all URI's were unique, and that all concepts has labels. The APD.csv (in Triples format) was used to recompile the HTML landing page. The APD_traits.csv and APD_categorical_values.csv files were used to recompile the YAML file for the AusTraits workflow. Deriving the HTML output from the Turtle serialization further and confirming AusTraits continued to build properly from the automatically regenerated YAML file, confirmed the files were complete and the process was accurate.

Code Availability

The code to compile the data into the selected output formats is available on the APD GitHub repository (https://github.com/traitecoevo/APD).

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Author contributions

E.H.W., H.S., R.V.G., and D.S.F. conceived the original idea.

E.H.W. led the writing of the manuscript.

E.H.W, R.B, C.B. and D.S.F. led the coding and the technical development of the RDF serialisations.

E.H.W, S.Y. and D.C let the AusTraits team review of trait concepts.

T.B., B.C., D.E., B.M, and H.S. offered expert reviews of traits.

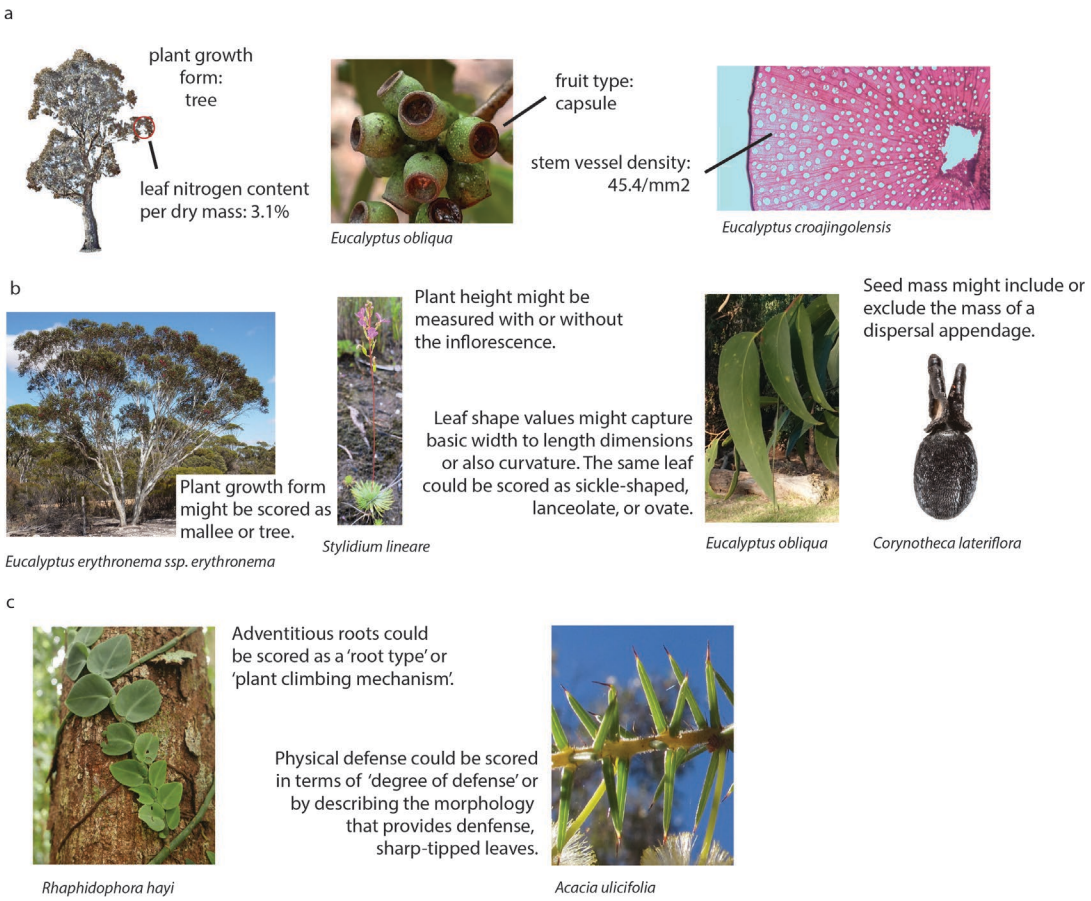
E.H.W., H.S., R.V.G, T.A., R.L.B., D.C., L.D., C.G., L.G., G.J.J., A.L., P.L., T.L., R.N., M.O., K.S., P.V., I.J.W., M.W., and S.Y. participated in the workshop reviews.

Competing interests

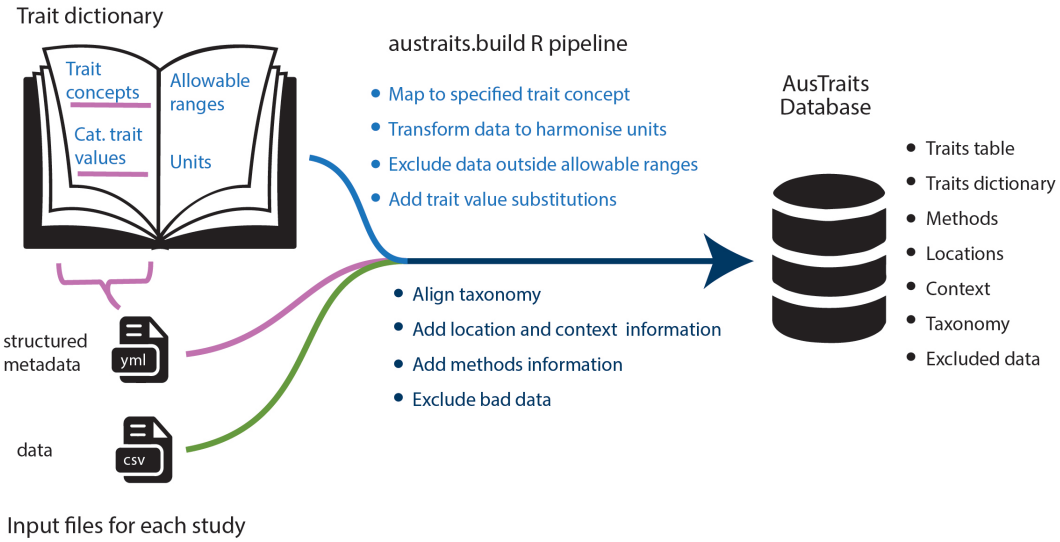
The authors declare no competing interests.

Figures

Figure 1



562 Figure 2.



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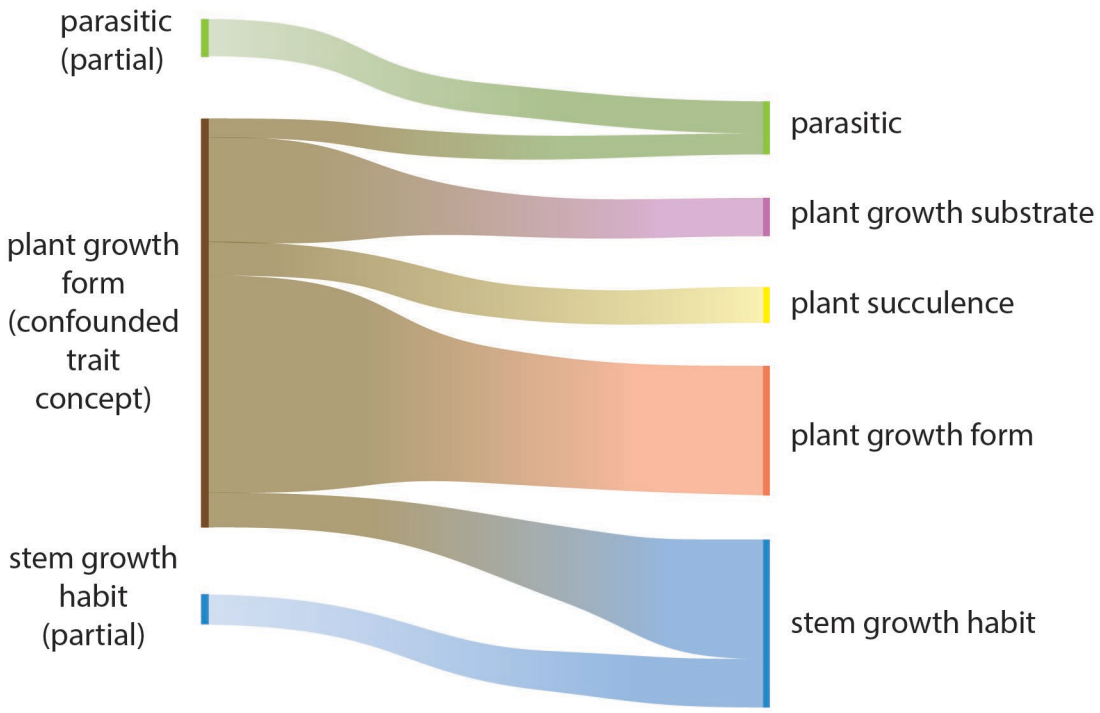
566 Figure 3.



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569 Figure 4.

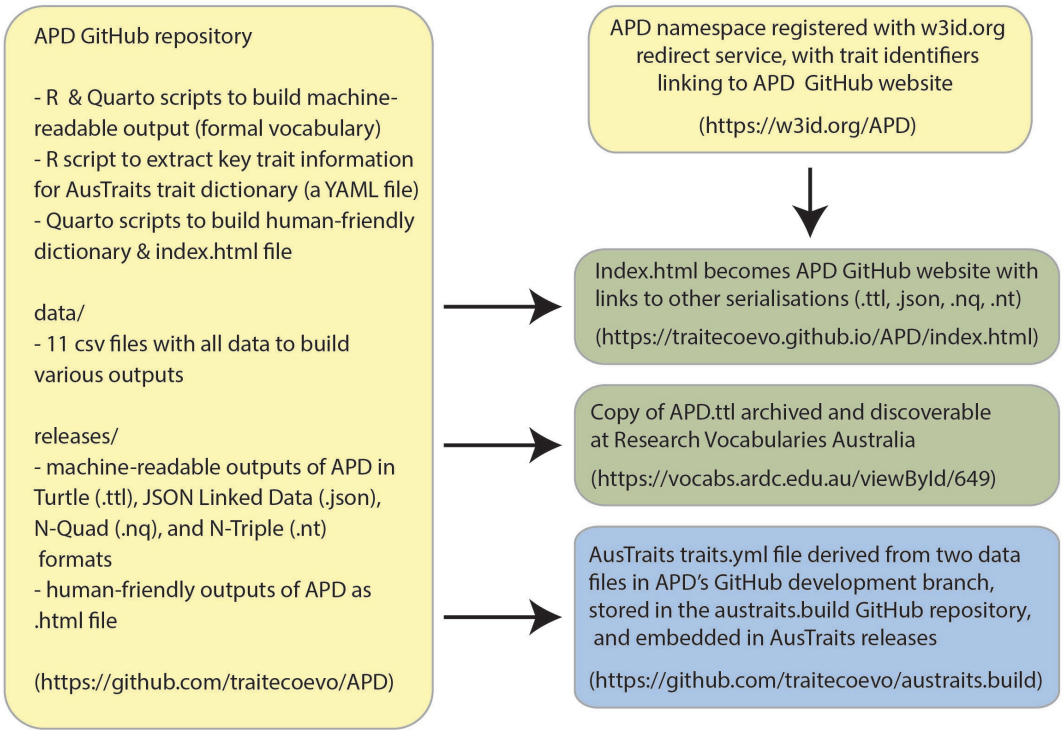

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Figure Legends

Figure 1. Explicit definitions and value descriptions are needed to reconcile inconsistencies in how researchers align plant phenotypic diversity with particular traits and trait values. a) For some taxa, for some phenotype observations, all researchers are likely to assign the same observation to the same trait and trait value; b) For other taxa, the same trait might not be consistently scored, especially without explicit definitions; c) Some phenotypes will be aligned to different traits or different trait values by different researchers, especially if clear trait and trait value descriptions are not available. Photo credits: Russell Barrett (*Corynotheca lateriflora* seed); John Cull, iNaturalist (*Eucalyptus obliqua* leaves); Gillian Kowalick (*Eucalyptus croajingolensis* cross-section); Dean Nicolle, iNaturalist (*Eucalyptus erythronema* subsp*. erythronema*); Elizabeth Wenk (*Acacia ulicifolia*; *Rhaphidophora hayi*); Dylan Wishart, iNaturalist (*Eucalyptus obliqua* fruits); hughberry, iNaturalist (*Stylidium lineare*).

Figure 2. A trait dictionary is an essential component of the AusTraits workflow, specifying i) trait concepts, ii) standard units, iii) allowable categorical trait values and iv) allowable ranges for numeric traits. The structured metadata file that accompanies each dataset explicitly maps data columns to specific trait concepts from the dictionary and includes substitutions to align categorical trait values with those in the dictionary. All four elements of each trait definition are then used by the traits.build R pipeline to integrate the data source into the AusTraits database.

Figure 3. The initial list of trait values mapped to the semantically messy trait concept `plant growth form` and the trait concepts `parasitic` and `stem growth habit` were able to be condensed from 68 to 53, despite adding more detailed trait values to parasitic, plant succulence and stem growth habit traits. For the APD, the retained trait values were mapped across 5 traits: plant growth form, plant succulence, plant growth substrate, parasitic and stem growth habit. The mixing of semantic concepts within 'plant growth form' had previously resulted in hybrid terms which could now be eliminated, such as "shrub_aquatic".

Figure 4. The APD inputs and stored on the project GitHub repository, the versioned outputs archived on the GitHub repository, Zenodo, and at the Australian Data Research Common's Research Vocabulary Australia (RVA) portal. APD has been registered as a namespace within w3id.org, with term URI's redirecting back to an HTML landing page within the GitHub repository. The APD inputs are also used to generate the traits.yml file required to build the AusTraits trait database.

Tables

Table 1. Information specified about trait concepts in a selection of trait thesauri, dictionaries, ontologies and databases. (citations: Plant Trait Ontology [30]; TOP [17]; EnvThes [31]; TRY [6]; GIFT [7]; BIEN [8]; LEDA [27]; BROT 2.0 [10]

	definitions	links to identical trait concepts	specifies units	specifies allowable ranges	specifies and defines allowable trait values	includes references	Machine readable definitions
Thesaurus, Dictionary or Ontology							
AusTraits Plant Dictionary (APD)	YES	YES	YES	YES	YES	partially	YES
Plant Trait Ontology (PTO)	YES	rarely	NO	NO	partially	NO	YES
Thesaurus Of Plant Characteristics (TOP)	YES	NO	YES	NO	YES	partially	partially
Thesaurus for long term ecological research, monitoring and experiments (EnvThes)	partially	partially	NO	NO	NO	NO	YES
Database							
TRY	partially	NO	YES	NO	NO	NO	NO
GIFT	NO	NO	YES	NO	YES	NO	NO
BIEN	NO	NO	YES	NO	YES	NO	NO
LEDA	YES	NO	YES	YES	YES	YES	NO
BROT	YES	YES	YES	partially	YES	YES	NO

617 **Table 2.** Traits were divided into clusters requiring different styles of review

Review category	Example trait concepts	Count of traits in category
AusTraits team review	Leaf N per leaf dry mass, Bark water content per unit bark dry mass, Palisade cell length	289
Expert review	Leaf Jmax per unit leaf area, Sapwood specific conductivity (Ks), Pollen grain aperture shape	114
Workshop discussion	Plant growth form, Seed shape, Fire response, Storage organ, Leaf shape	112

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621 **Table 3.** Metadata provided for each trait concept, including a description of each metadata
622 field and the published annotation property onto which this information is mapped.

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APD Field	Description	Type	Annotation property*	Example for fruit length
Identifiers and Labels				
Label	A concise English label for the trait	Text string	SKOS:label	Fruit length
AusTraits database label	A label for the trait where words are connected by underscores	Text string	SKOS:altLabel	fruit_length
Trait ID	A numeric identifier	Text string	dcterms:identifier	trait_0012512
Descriptions				
Description	A pair of descriptions, ranging from 1-3 sentences that clearly indicates the trait's scope. One description is written in plain English and for the second, technical terms are linked to published ontologies whenever possible.	Text string	dcterms:description	Linear dimension from the base to the apex of a fresh fruit, even if this is not the longest dimension. A fruit morphology trait [TO:0002629] which is the length [PATO:0000122] of a fresh [EnvThes:21976] fruit [PO:0009001] from the fruit proximal end [PO:0008002] (base) to the fruit distal end [PO:0008001] (apex).
Comments	Additional notes about the scope of the trait or acceptable methods.	Text string	RDFS:comment	(none)
Metadata required for processing				
Type	Type of trait, specifying if traits are categorical, numeric, or ordinal	Entity IRI**	ETS:valueType	continuous variable
Units	The preferred units for the trait, conforming to the Unified Code for Units of Measure (UCUM). There are often two entries for units, one that is a string and the second which links to a units of measurement axiom.	Entity IRI and/or Text string	ETS:expectedUnit	mm
Allowed values min & Allowed values max	A lower and upper boundary for accepted numerical values	Number	ETS:minAllowedValue & ETS:maxAllowedValue	0.01 - 2000
Allowed values levels	Allowable terms (trait values) for categorical traits	Text string	ETS:factorLevels***	NA
Metadata to increase trait concept findability				
Measured structure	Indication of what organ(s), tissue(s), or other plant structure is being measured for a given trait	Entity IRI	iadopt:hasContextObject	Fruit; reproductive shoot system
Measured characteristic	Keywords pertaining to what categorical or numeric property is measured, such as whether the measurement is a length, volume, duration of time, or shape	Entity IRI	oboe-core:MeasuredCharacteristic	Length; size
Keyword	Additional descriptors beyond the trait category, tissue entity and measured characteristic which facilitate information retrieval	Entity IRI and/or text string	SIO:000147 (keyword)	reproduction
Metadata to increase trait concept documentation				

References	Key sources for trait concept, scope and definition	Entity IRI	dcterms:references	Pérez-Harguindeguy 2013 Kew Seed Information Database 2022
Scope of trait concept	The scope of the trait, specifying taxonomic or morphological groupings to which the trait concept applies	Text string	SKOS:scopeNote	NA
Date created	The date when the trait metadata was first created	Date	dcterms:created (date created)	14/07/2021
Date modified	The date when the trait metadata was last revised	Date	dcterms:modified (date modified)	30/11/2021
Previous trait labels	Trait labels previously used for this trait concept	Text string	SKOS:changeNote	NA
Reviewer	People who have reviewed the trait concept, identified by ORCID number	Entity IRI	datacite/4.4:isReviewedBy	Elizabeth Wenk, Hervé Sauquet, Russell Barrett, Carl Gosper, Lydia Guja, Gregory J. Jordan, Mark Ooi, Karen D. Sommerville, Lily Dun
UCUM code	Preferred units, expressed as a UCUM code	Text string	uom:UCUM_code	mm
SI code	Preferred units, expressed in SI format	Entity IRI	uom:SI_code	millimetre
Metadata to increase trait concept interoperability				
Exact match	Identical trait concepts in other trait databases or ontologies	Entity IRI and/or text string	SKOS:exactMatch	-Fruit length [TOP92] (https://top-thesaurus.org/index) -Fruit length [TRY:918] (https://www.try-db.org/de/de.php) -fruit_length [GIFT:3.13] (https://gift.uni-goettingen.de) -AverageFruitLength_cm; MinFruitLength_cm; MaxFruitLength_cm
Close match	Similar trait concepts in other trait databases or ontologies	Entity IRI and/or text string	SKOS:closeMatch	maximum fruit length; minimum fruit length [BIEN] (https://bien.nceas.ucsb.edu/bien/biendata)
Related match	Related trait concepts in other trait databases or ontologies	Entity IRI and/or text string	SKOS:relatedMatch	

* The annotation properties indicate the source ontology for each field, with the abbreviations linked to the source vocabularies as follows: SKOS = http://www.w3.org/2004/02/skos/core#; dcterms = http://purl.org/dc/terms/; RDFS = http://www.w3.org/2000/01/rdf-schema#; ETS = http://terminologies.gfbio.org/terms/ETS/; uom = https://w3id.org/uom/; iadopt = https://w3id.org/iadopt/ont/; oboe-core = http://ecoinformatics.org/oboe/oboe.1.2/oboe-core.owl#; SIO = http://semanticscience.org/resource/; datacite = http://purl.org/datacite/v4.4/

631 ** 'Entity IRI' indicates that the information within this field is a term that has its own URL
632 (e.g. references, reviewers ORCIDs) or Internationalized Resource Identifier (IRI; for terms in
633 a published vocabulary/ontology).

634 *** Allowable categorical trait values (allowable levels) are mapped in APD as SKOS:member
635 of a collection (for each trait) or owl:individual that are instances of a trait (owl:class)

636

637 **Table 4**. Explicitly listing synonyms as part of trait value definitions ensured alternative
638 terminology can be consistently mapped to the term used in the APD, as illustrated here for
639 seed surface texture.

Trait Value	Synonyms
bumpy	colliculate, verrucate, papillate, tuberculate, undulate
grooved	
netted	reticulate, honey-combed
papery	chartaceous
pitted	foveolate, foveate, dimpled, lacunose, punctate
ribbed	carinate, costate, fluted, lineate, lineolate, ridged, scalariform, striate, strigose
rough	scabrous
scaly	scurfy, squarrose
smooth	glabrous
spiny	echinulate
wrinkled	rugose, rugulose, bullate

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643 Supplementary Tables

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645 **Supplementary Table 1**. Number of traits in each of the hierarchical trait groupings.

trait grouping	number of trait concepts within group*
biochemical trait	
mineral and ion content trait	
leaf mineral and ion content trait	
live leaf mineral and ion content trait	33
senesced leaf mineral and ion content trait	16
stem mineral and ion content trait	17
wood mineral and ion content trait	7
senesced wood mineral and ion content trait	6
bark mineral and ion content trait	9
root mineral and ion content trait	3
reproductive shoot system mineral and ion content trait	13
cell or tissue mineral and ion content trait	14
metabolite content trait	
carbohydrate content trait	13
lipid content trait	1
phenolic compound content trait	5
pigment content trait	9
protein content trait	4
stable isotope ratio determination	14
plant morphology trait	
whole plant morphology trait	5
plant embryo morphology trait	8
plant structure morphology trait	6
portion of plant tissue morphology trait	11
plant cell morphology trait	6
leaf morphology trait	30
leaf size trait	11
leaf mass trait	16
leaf shape trait	10
leaf position trait	5
leaf stomatal complex morphology trait	6
leaf optical properties trait	4
stem morphology trait	34
stem mass trait	6
bark morphology trait	9
root system morphology trait	14
reproductive shoot system morphology trait	3
floral organ morphology trait	4
perianth morphology trait	12

androecium morphology trait	14
gynoecium morphology trait	8
fruit morphology trait	13
seed morphology trait	16
vascular tissue morphology trait	5
leaf vein morphology trait	4
xylem vessel morphology trait	10
plant structure strength trait	10
biological process trait, physiological process trait	
photosynthetic trait	2
gas exchange trait	13
photosynthetic rate trait	7
respiration rate trait	4
transpiration rate trait	6
carbon dioxide concentration trait	6
photosystem performance trait	11
water transport trait, hydraulic trait	44
nutrient recycling trait	2
life history trait	5
whole plant phenotype trait	16
plant phenological trait	16
interspecific interactions trait	8
genetic structure trait	2
reproductive structure life history trait	14
fire response trait	32
chemical stress sensitivity trait	3
environmental tolerance trait	16

* The total number of traits in this table is greater than the total number of traits in APD, since some traits appear in multiple categories.

Supplementary Table 2. Output for the trait `life history` from APD.ttl

APD:trait_0030012

a owl:Class, skos:Concept ;

rdfs:label "Life history"@en ;

skos:prefLabel "Life history"@en ;

skos:altLabel "life_history" ;

skos:definition "Categorical description of the duration [PATO:0001309] of a plant's lifespan (longevity [NCIT:C153298]), from seed germination [GO:0009845] to death [GO:0016265]."@en, "Categorical description of the duration of a plant's lifespan, from germination to death."@en ;

dcterms:description "Categorical description of the duration [PATO:0001309] of a plant's lifespan (longevity [NCIT:C153298]), from seed germination [GO:0009845] to death [GO:0016265]."@en, "Categorical description of the duration of a plant's lifespan, from germination to death."@en ;

rdfs:comment "Studies will differ in the subset of terms they use to describe a plant's life history, such that some researchers will distinguish between ephemeral and annual species, and other researchers will group these life history categories together under `annual`. In addition, only a subset of studies will use the term `short-lived perennial`; the majority will score all perennial plants as `perennial`. Rangeland studies and post-fire studies are those most likely to score species as `ephemeral` or `short-lived perennial`, as these are environments where perennial species' lifespans are often divided into those that are short-lived due to environmental conditions and those that are able to persist through the environmentally unfavourable period."@en ;

dcterms:identifier "trait_0030012" ;

ets:valueType obo:STATO_0000252 ;

oboecore:MeasuredCharacteristic obo:PATO_0000165, obo:PATO_0001309, obo:PATO_0001995 ;

ont:hasContextObject obo:PO_0000003 ;

skos:narrower APD:life_history_annual, APD:life_history_biennial, APD:life_history_ephemeral, APD:life_history_perennial, APD:life_history_short_lived_perennial ;

datacite:IsReviewedBy <https://orcid.org/0000-0001-5640-5910>, <https://orcid.org/0000-0001-8305-3236>, <https://orcid.org/0000-0001-8338-9143>, <https://orcid.org/0000-0002-0712-5143>, <https://orcid.org/0000-0002-1773-6597>, <https://orcid.org/0000-0002-6033-2766>, <https://orcid.org/0000-0003-0360-8321>, <https://orcid.org/0000-0003-1116-9402>, <https://orcid.org/0000-0003-2008-7062>, <https://orcid.org/0000-0003-3568-2606> ;

dcterms:created "14/07/2021"^^<xsd:date> ;

dcterms:reviewed "31/10/2022"^^<xsd:date> ;

dcterms:references <https://doi.org/10.1071/BT12225>, <https://uol.de/en/landeco/research/leda/standards> ;

SIO:SIO_000147 obo:GO_0016265, obo:NCIT_C153298 ;

693 rdfs:subClassOf APD:trait_group_0030006 ;

694 skos:broader APD:trait_group_0030006 ;

695 skos:closeMatch "plant lifespan and age of first flowering [LEDA:1.3] (https://www.try-
696 db.org/de/de.php)" ;

697 skos:exactMatch obo:TO_0002725, "Plant lifespan (longevity) [TRY:59] (https://www.try-
698 db.org/de/de.php)", "lifecycle [GIFT:2.1.1] (https://gift.uni-goettingen.de)" ;

699 skos:closeMatch "plant lifespan and age of first flowering [LEDA:1.3] (https://www.try-
700 db.org/de/de.php)" ;

701 skos:relatedMatch "Growth form [BROT:1] (http://doi.org/10.1038/sdata.2018.135)
702 (http://doi.org/10.1038/sdata.2018.135)" ;

703 skos:scopeNote "none"@en ;

704 skos:inScheme "https://w3id.org/APD/traits" .

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708 Supplementary Table 3. Traits within the APD.

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label	alternate label (AusTraits `trait_name`)	APD identifier
Biochemical Traits		
Leaf aluminium (Al) content per unit leaf dry mass	leaf_Al_per_dry_mass	trait_0000012
Leaf boron (B) content per unit leaf dry mass	leaf_B_per_dry_mass	trait_0000014
Leaf carbon (C) content per unit leaf dry mass	leaf_C_per_dry_mass	trait_0000016
Leaf calcium (Ca) content per unit leaf dry mass	leaf_Ca_per_dry_mass	trait_0000018
Leaf chlorine (Cl) content per unit leaf dry mass	leaf_Cl_per_dry_mass	trait_0000020
Leaf chromium (Cr) content per unit leaf dry mass	leaf_Cr_per_dry_mass	trait_0000022
Leaf cobalt (Co) content per unit leaf dry mass	leaf_Co_per_dry_mass	trait_0000024
Leaf copper (Cu) content per unit leaf dry mass	leaf_Cu_per_dry_mass	trait_0000026
Leaf iron (Fe) content per unit leaf dry mass	leaf_Fe_per_dry_mass	trait_0000028
Leaf potassium (K) content per unit leaf area	leaf_K_per_area	trait_0000029
Leaf potassium (K) content per unit leaf dry mass	leaf_K_per_dry_mass	trait_0000030
Leaf magnesium (Mg) content per unit leaf dry mass	leaf_Mg_per_dry_mass	trait_0000032
Leaf manganese (Mn) content per unit leaf dry mass	leaf_Mn_per_dry_mass	trait_0000034
Leaf molybdenum (Mo) content per unit leaf dry mass	leaf_Mo_per_dry_mass	trait_0000036
Leaf nitrogen (N) content per unit leaf area	leaf_N_per_area	trait_0000037
Leaf nitrogen (N) content per unit leaf dry mass	leaf_N_per_dry_mass	trait_0000038
Leaf sodium (Na) content per unit leaf dry mass	leaf_Na_per_dry_mass	trait_0000040
Leaf nickel (Ni) content per unit leaf dry mass	leaf_Ni_per_dry_mass	trait_0000042
Leaf phosphorus (P) content per unit leaf area	leaf_P_per_area	trait_0000043
Leaf phosphorus (P) content per unit leaf dry mass	leaf_P_per_dry_mass	trait_0000044
Leaf sulphur (S) content per unit leaf dry mass	leaf_S_per_dry_mass	trait_0000046
Leaf selenium (Se) content per unit leaf dry mass	leaf_Se_per_dry_mass	trait_0000048
Leaf silicon (Si) content per unit leaf dry mass	leaf_Si_per_dry_mass	trait_0000050
Leaf zinc (Zn) content per unit leaf dry mass	leaf_Zn_per_dry_mass	trait_0000052
Leaf carbon to nitrogen ratio (C/N)	leaf_CN_ratio	trait_0000090
Leaf nitrogen to phosphorus ratio (N/P) per unit leaf dry mass	leaf_NP_ratio	trait_0000091
Senesced leaf aluminium (Al) content per unit leaf dry mass	leaf_senesced_Al_per_dry_mass	trait_0000112
Senesced leaf boron (B) content per unit leaf dry mass	leaf_senesced_B_per_dry_mass	trait_0000114
Senesced leaf carbon (C) content per unit leaf dry mass	leaf_senesced_C_per_dry_mass	trait_0000116
Senesced leaf calcium (Ca) content per unit leaf dry mass	leaf_senesced_Ca_per_dry_mass	trait_0000118
Senesced leaf copper (Cu) content per unit leaf dry mass	leaf_senesced_Cu_per_dry_mass	trait_0000126
Senesced leaf iron (Fe) content per unit leaf dry mass	leaf_senesced_Fe_per_dry_mass	trait_0000128
Senesced leaf potassium (K) content per unit leaf dry mass	leaf_senesced_K_per_dry_mass	trait_0000130
Senesced leaf magnesium (Mg) content per unit leaf dry mass	leaf_senesced_Mg_per_dry_mass	trait_0000132
Senesced leaf manganese (Mn) content per unit leaf dry mass	leaf_senesced_Mn_per_dry_mass	trait_0000134
Senesced leaf molybdenum (Mo) content per unit leaf dry mass	leaf_senesced_Mo_per_dry_mass	trait_0000136

Senesced leaf nitrogen (N) content per unit leaf dry mass	leaf_senesced_N_per_dry_mass	trait_0000138
Senesced leaf sodium (Na) content per unit leaf dry mass	leaf_senesced_Na_per_dry_mass	trait_0000140
Senesced leaf nickel (Ni) content per unit leaf dry mass	leaf_senesced_Ni_per_dry_mass	trait_0000142
Senesced leaf phosphorus (P) content per unit leaf dry mass	leaf_senesced_P_per_dry_mass	trait_0000144
Senesced leaf sulphur (S) content per unit leaf dry mass	leaf_senesced_S_per_dry_mass	trait_0000146
Senesced leaf zinc (Zn) content per unit leaf dry mass	leaf_senesced_Zn_per_dry_mass	trait_0000152
Leaf nitrogen resorption	leaf_N_resorption	trait_0022012
Leaf phosphorus resorption	leaf_P_resorption	trait_0022013
Stem carbon (C) content per unit stem dry mass	stem_C_per_dry_mass	trait_0000216
Stem nitrogen (N) content per unit stem dry mass	stem_N_per_dry_mass	trait_0000238
Wood carbon (C) content per unit wood dry mass	wood_C_per_dry_mass	trait_0000416
Wood calcium (Ca) content per unit wood dry mass	wood_Ca_per_dry_mass	trait_0000418
Wood potassium (K) content per unit wood dry mass	wood_K_per_dry_mass	trait_0000430
Wood magnesium (Mg) content per unit wood dry mass	wood_Mg_per_dry_mass	trait_0000432
Wood nitrogen (N) content per unit wood dry mass	wood_N_per_dry_mass	trait_0000438
Wood sodium (Na) content per unit wood dry mass	wood_Na_per_dry_mass	trait_0000440
Wood phosphorus (P) content per unit wood dry mass	wood_P_per_dry_mass	trait_0000444
Dead wood calcium (Ca) content per unit dead wood dry mass	wood_dead_Ca_per_dry_mass	trait_0000518
Dead wood potassium (K) content per unit dead wood dry mass	wood_dead_K_per_dry_mass	trait_0000530
Dead wood magnesium (Mg) content per unit dead wood dry mass	wood_dead_Mg_per_dry_mass	trait_0000532
Dead wood nitrogen (N) content per unit dead wood dry mass	wood_dead_N_per_dry_mass	trait_0000538
Dead wood sodium (Na) content per unit dead wood dry mass	wood_dead_Na_per_dry_mass	trait_0000540
Dead wood phosphorus (P) content per unit dead wood dry mass	wood_dead_P_per_dry_mass	trait_0000544
Bark aluminium (Al) content per unit bark dry mass	bark_Al_per_dry_mass	trait_0000612
Bark boron (B) content per unit bark dry mass	bark_B_per_dry_mass	trait_0000614
Bark carbon (C) content per unit bark dry mass	bark_C_per_dry_mass	trait_0000616
Bark calcium (Ca) content per unit bark dry mass	bark_Ca_per_dry_mass	trait_0000618
Bark copper (Cu) content per unit bark dry mass	bark_Cu_per_dry_mass	trait_0000626
Bark iron (Fe) content per unit bark dry mass	bark_Fe_per_dry_mass	trait_0000628
Bark potassium (K) content per unit bark dry mass	bark_K_per_dry_mass	trait_0000630
Bark magnesium (Mg) content per unit bark dry mass	bark_Mg_per_dry_mass	trait_0000632
Bark manganese (Mn) content per unit bark dry mass	bark_Mn_per_dry_mass	trait_0000634
Bark nitrogen (N) content per unit bark dry mass	bark_N_per_dry_mass	trait_0000638
Bark sodium (Na) content per unit bark dry mass	bark_Na_per_dry_mass	trait_0000640
Bark phosphorus (P) content per unit bark dry mass	bark_P_per_dry_mass	trait_0000644
Bark sulphur (S) content per unit bark dry mass	bark_S_per_dry_mass	trait_0000646
Bark zinc (Zn) content per unit bark dry mass	bark_Zn_per_dry_mass	trait_0000652

Root carbon (C) content per unit root dry mass	root_C_per_dry_mass	trait_0000816
Root nitrogen (N) content per unit root dry mass	root_N_per_dry_mass	trait_0000838
Root phosphorus (P) content per unit root dry mass	root_P_per_dry_mass	trait_0000844
Flower nitrogen (N) content per unit flower dry mass	flower_N_per_dry_mass	trait_0001038
Fruit calcium (Ca) content per unit fruit dry mass	fruit_Ca_per_dry_mass	trait_0001118
Fruit potassium (K) content per unit fruit dry mass	fruit_K_per_dry_mass	trait_0001130
Fruit magnesium (Mg) content per unit fruit dry mass	fruit_Mg_per_dry_mass	trait_0001132
Fruit nitrogen (N) content per unit fruit dry mass	fruit_N_per_dry_mass	trait_0001138
Fruit phosphorus (P) content per unit fruit dry mass	fruit_P_per_dry_mass	trait_0001144
Fruit sulphur (S) content per unit fruit dry mass	fruit_S_per_dry_mass	trait_0001146
Seed calcium (Ca) content per unit seed dry mass	seed_Ca_per_seed_dry_mass	trait_0001218
Seed potassium (K) content per unit seed dry mass	seed_K_per_seed_dry_mass	trait_0001230
Seed magnesium (Mg) content per unit seed dry mass	seed_Mg_per_seed_dry_mass	trait_0001232
Seed nitrogen (N) content per unit seed dry mass	seed_N_per_seed_dry_mass	trait_0001238
Seed phosphorus (P) content per unit seed dry mass	seed_P_per_seed_dry_mass	trait_0001244
Seed sulphur (S) content per unit seed dry mass	seed_S_per_seed_dry_mass	trait_0001246
Leaf cell wall nitrogen (N) per unit cell wall dry mass	leaf_cell_wall_N_per_cell_wall_dry_mass	trait_0001511
Leaf cell wall nitrogen (N) per unit leaf N content	leaf_cell_wall_N_per_leaf_N	trait_0001512
Leaf rubisco nitrogen (N) content per unit leaf N content	leaf_rubisco_N_per_total_leaf_N	trait_0001513
Leaf thylakoid protein nitrogen (N) content per unit leaf N content	leaf_thylakoid_N_per_total_leaf_N	trait_0001514
Leaf epidermis calcium (Ca) content per unit leaf fresh mass	leaf_epidermis_Ca_per_fresh_mass	trait_0001611
Leaf hypodermis calcium (Ca) content per unit leaf fresh mass	leaf_hypodermis_Ca_per_fresh_mass	trait_0001612
Leaf internal parenchyma cell calcium (Ca) content per unit leaf fresh mass	leaf_internal_parenchyma_Ca_per_fresh_mass	trait_0001613
Leaf palisade mesophyll cell calcium (Ca) content per unit leaf fresh mass	leaf_palisade_mesophyll_Ca_per_fresh_mass	trait_0001614
Leaf sclerenchyma cell calcium (Ca) content per unit leaf fresh mass	leaf_sclerenchyma_Ca_per_fresh_mass	trait_0001615
Leaf spongy mesophyll cell calcium (Ca) content per unit leaf fresh mass	leaf_spongy_mesophyll_Ca_per_fresh_mass	trait_0001616
Leaf epidermis phosphorus (P) content per unit leaf fresh mass	leaf_epidermis_P_per_fresh_mass	trait_0001661
Leaf hypodermis phosphorus (P) content per unit leaf fresh mass	leaf_hypodermis_P_per_fresh_mass	trait_0001662
Leaf internal parenchyma cell phosphorus (P) content per unit leaf fresh mass	leaf_internal_parenchyma_P_per_fresh_mass	trait_0001663
Leaf palisade mesophyll cell phosphorus (P) content per unit leaf fresh mass	leaf_palisade_mesophyll_P_per_fresh_mass	trait_0001664
Leaf sclerenchyma cell phosphorus (P) content per unit leaf fresh mass	leaf_sclerenchyma_P_per_fresh_mass	trait_0001665
Leaf spongy mesophyll cell phosphorus (P) content per unit leaf fresh mass	leaf_spongy_mesophyll_P_per_fresh_mass	trait_0001666

Leaf total non-structural carbohydrate content per unit leaf area	leaf_total_non-structural_carbohydrates_per_area	trait_0002021
Leaf total non-structural carbohydrate content per unit leaf dry mass	leaf_total_non-structural_carbohydrates_per_mass	trait_0002022
Leaf cellulose content per unit leaf dry mass	leaf_cellulose_per_dry_mass	trait_0002024
Leaf starch content per unit leaf area	leaf_starch_per_area	trait_0002025
Leaf soluble starch content per unit leaf area	leaf_soluble_starch_per_area	trait_0002027
Leaf soluble starch content per unit leaf dry mass	leaf_soluble_starch_per_mass	trait_0002028
Leaf soluble sugar content per unit leaf area	leaf_soluble_sugars_per_area	trait_0002031
Leaf soluble sugar content per unit leaf dry mass	leaf_soluble_sugars_per_mass	trait_0002032
Leaf soluble protein content per unit leaf area	leaf_soluble_protein_per_area	trait_0002035
Leaf insoluble protein content per unit leaf area	leaf_insoluble_protein_per_area	trait_0002037
Leaf lignin content per unit leaf dry mass	leaf_lignin_per_dry_mass	trait_0002050
Total leaf phenolic content per unit leaf dry mass	leaf_phenol_per_dry_mass	trait_0002052
Leaf tannin content per unit leaf dry mass	leaf_tannin_per_dry_mass	trait_0002054
Leaf carotenoid content per unit leaf area	leaf_carotenoid_per_area	trait_0002055
Leaf carotenoid content per unit leaf dry mass	leaf_carotenoid_per_dry_mass	trait_0002056
Leaf total chlorophyll content (chlorophyll A + B) per unit leaf area	leaf_chlorophyll_per_area	trait_0002081
Leaf total chlorophyll content (chlorophyll A + B) per unit leaf dry mass	leaf_chlorophyll_per_dry_mass	trait_0002082
Leaf chlorophyll A content per unit leaf area	leaf_chlorophyll_A_per_area	trait_0002083
Leaf chlorophyll A content per unit leaf dry mass	leaf_chlorophyll_A_per_dry_mass	trait_0002084
Leaf chlorophyll B content per unit leaf area	leaf_chlorophyll_B_per_area	trait_0002085
Leaf chlorophyll B content per unit leaf dry mass	leaf_chlorophyll_B_per_dry_mass	trait_0002086
Ratio of leaf chlorophyll A content to leaf chlorophyll B content	leaf_chlorophyll_A_B_ratio	trait_0002087
Leaf rubisco content per unit leaf dry mass	leaf_rubisco_per_leaf_dry_mass	trait_0002090
Stem soluble starch content per unit stem dry mass	stem_soluble_starch_per_mass	trait_0002127
Stem soluble sugar content per unit stem dry mass	stem_soluble_sugars_per_mass	trait_0002131
Bark cellulose content per unit bark dry mass	bark_cellulose_per_dry_mass	trait_0002224
Bark lignin content per unit bark dry mass	bark_lignin_per_dry_mass	trait_0002250
Bark tannin content per unit bark dry mass	bark_tannin_per_dry_mass	trait_0002255
Root soluble starch content per unit root dry mass	root_soluble_starch_per_mass	trait_0002327
Root soluble sugar content per unit root dry mass	root_soluble_sugars_per_mass	trait_0002331
Seed protein content per unit seed dry mass	seed_protein_per_seed_dry_mass	trait_0002534
Seed oil content per unit seed dry mass	seed_oil_per_seed_dry_mass	trait_0002544
Leaf ash content per unit leaf dry mass	leaf_ash_per_dry_mass	trait_0002822
Bark ash content per unit bark dry mass	bark_ash_per_dry_mass	trait_0002824
Bark stable carbon isotope composition (delta13C)	bark_delta13C	trait_0003011
Leaf stable carbon isotope composition (delta13C)	leaf_delta13C	trait_0003012
Stem stable carbon isotope composition (delta13C)	stem_delta13C	trait_0003013

Root stable carbon isotope composition (delta13C)	root_delta13C	trait_0003014
Wood stable carbon isotope composition (delta13C)	wood_delta13C	trait_0003015
Bark stable nitrogen isotope composition (delta15N)	bark_delta15N	trait_0003031
Leaf stable nitrogen isotope composition (delta15N)	leaf_delta15N	trait_0003032
Stem stable nitrogen isotope composition (delta15N)	stem_delta15N	trait_0003033
Root stable nitrogen isotope composition (delta15N)	root_delta15N	trait_0003034
Wood stable nitrogen isotope composition (delta15N)	wood_delta15N	trait_0003035
Leaf xylem stable nitrogen isotope composition (delta15N)	leaf_xylem_delta15N	trait_0003052
Root xylem stable nitrogen isotope composition (delta15N)	root_xylem_delta15N	trait_0003053
Leaf stable oxygen isotope composition (delta18O)	leaf_delta18O	trait_0003072
Stem water stable oxygen isotope composition (delta18O)	stem_water_delta18O	trait_0003092
Plant Morphology Trait		
Plant canopy width	plant_width	trait_0010021
Plant canopy breadth	plant_breadth	trait_0010022
Plant vegetative height	plant_height	trait_0010023
Stem diameter at breast height	plant_diameter_breast_height	trait_0010024
Stem count	stem_count	trait_0010025
Plant spinescence	plant_spinescence	trait_0010070
Embryo colour	embryo_colour	trait_0010110
Cotyledon function	cotyledon_function	trait_0010111
Cotyledon position at germination	cotyledon_position	trait_0010112
Cotyledon hairiness	cotyledon_hairs	trait_0010113
Hypocotyl hairiness	seedling_hypocotyl_hairs	trait_0010114
Seedling first true leaf type	seedling_first_node_leaf_type	trait_0010160
Seedling first node leaf count	seedling_first_node_leaf_count	trait_0010161
Seedling germination location	seedling_germination_location	trait_0010162
Leaf area	leaf_area	trait_0011211
Leaflet area	leaflet_area	trait_0011212
Leaf length	leaf_length	trait_0011213
Leaf width	leaf_width	trait_0011214
Leaf thickness	leaf_thickness	trait_0011215
Leaf dry mass	leaf_dry_mass	trait_0011216
Leaflet dry mass	leaflet_dry_mass	trait_0011217
Leaf fresh mass	leaf_fresh_mass	trait_0011218
Petiole length	petiole_length	trait_0011219
Petiole width	petiole_width	trait_0011220
Leaf mass per area	leaf_mass_per_area	trait_0011230
Leaf lamina mass per area	leaf_lamina_mass_per_area	trait_0011231
Leaf tissue density	leaf_density	trait_0011232
Leaf area ratio (LAR)	leaf_area_ratio	trait_0011260

Leaf mass fraction	leaf_mass_fraction	trait_0011261
Leaf dry matter content (LDMC)	leaf_dry_matter_content	trait_0011262
Leaf fresh mass per leaf area	leaf_fresh_mass_per_area	trait_0011263
Leaf water content per unit leaf area (leaf succulence)	leaf_water_content_per_area	trait_0011264
Leaf water content per unit leaf dry mass	leaf_water_content_per_dry_mass	trait_0011265
Leaf water content per unit leaf fresh mass	leaf_water_content_per_fresh_mass	trait_0011266
Leaf water content per unit saturated leaf mass	leaf_water_content_per_saturated_mass	trait_0011267
Leaf cell wall fraction	leaf_cell_wall_fraction	trait_0011268
Leaf type	leaf_type	trait_0011310
Leaf shape	leaf_shape	trait_0011311
Leaf base shape	leaf_base_shape	trait_0011312
Leaf margin	leaf_margin	trait_0011313
Leaf margin posture	leaf_margin_posture	trait_0011314
Leaf lobation	leaf_lobation	trait_0011315
Leaf compoundness	leaf_compoundness	trait_0011316
Leaf divisions	leaf_lamina_division	trait_0011317
Leaf lamina posture (leaf 3-dimensionality)	leaf_posture_numeric	trait_0011318
Leaf lamina posture (leaf 3-dimensional shape)	leaf_lamina_posture	trait_0011319
Leaf glaucousness	leaf_glaucousness	trait_0011360
Mature leaf hairiness	leaf_hairs_adult_leaves	trait_0011361
Juvenile phase leaf hairiness	leaf_hairs_juvenile_leaves	trait_0011362
Immature leaf hairiness	leaf_hairs_immature_leaves	trait_0011363
Leaf phyllotaxis	leaf_phyllotaxis	trait_0011410
Leaf arrangement	leaf_arrangement	trait_0011411
Leaf axil angle	leaf_axil_angle	trait_0011412
Leaf inclination angle	leaf_inclination_angle	trait_0011413
Leaf pendulousness	leaf_pendulousness	trait_0011414
Cuticle thickness on the lower leaf surface	leaf_cuticle_thickness_abaxial	trait_0011510
Cuticle thickness on the upper leaf surface	leaf_cuticle_thickness_adaxial	trait_0011511
Leaf epidermis thickness	leaf_epidermis_thickness	trait_0011512
Lower leaf side epidermis thickness	leaf_epidermis_thickness_abaxial	trait_0011513
Upper leaf side epidermis thickness	leaf_epidermis_thickness_adaxial	trait_0011514
Average leaf epidermal cell density	leaf_epidermal_cell_density_both_sides	trait_0011515
Lower leaf side epidermal cell density	leaf_epidermal_cell_density_abaxial	trait_0011516
Upper leaf side epidermal cell density	leaf_epidermal_cell_density_adaxial	trait_0011517
Lower leaf side hypodermis thickness	leaf_hypodermis_thickness_abaxial	trait_0011518
Upper leaf side hypodermis thickness	leaf_hypodermis_thickness_adaxial	trait_0011519
Lower palisade mesophyll thickness	leaf_palisade_tissue_thickness_abaxial	trait_0011520
Upper palisade mesophyll thickness	leaf_palisade_tissue_thickness_adaxial	trait_0011521
Palisade cell length	leaf_palisade_cell_length	trait_0011522
Palisade cell width	leaf_palisade_cell_width	trait_0011523

Number of layers of palisade cells	leaf_palisade_layer_number	trait_0011524
Spongy mesophyll cell thickness	leaf_spongy_mesophyll_thickness	trait_0011525
Cell cross-sectional area	cell_cross-sectional_area	trait_0011526
Stomatal density on the lower leaf surface	leaf_stomatal_density_abaxial	trait_0011610
Stomatal density on the upper leaf surface	leaf_stomatal_density_adaxial	trait_0011611
Stomatal density averaged across both leaf surfaces	leaf_stomatal_density_average	trait_0011612
Stomatal distribution	leaf_stomatal_distribution	trait_0011613
Stomatal hairiness	leaf_stomatal_hairs	trait_0011614
Guard cell length	leaf_guard_cell_length	trait_0011615
Leaf visible light transmission	leaf_transmission	trait_0011710
Leaf visible light absorption	leaf_absorption	trait_0011711
Leaf visible light reflection	leaf_reflectance	trait_0011712
Leaf infra-red light reflection	leaf_reflectance_near_infrared	trait_0011713
Stem cross-sectional area	stem_cross_sectional_area	trait_0011811
Wood cross-sectional area	sapwood_cross_sectional_area	trait_0011812
Terminal twig cross-sectional area	branch_terminal_twig_cross_sectional_area	trait_0011813
Terminal twig length	branch_terminal_twig_length	trait_0011814
Wood density	wood_density	trait_0011815
Herbaceous stem density	stem_density	trait_0011816
Huber value	huber_value	trait_0011911
Leaf dry mass to stem dry mass ratio	leaf_mass_to_stem_mass_ratio	trait_0011912
Stem dry mass to vegetative shoot dry mass ratio (support fraction)	stem_mass_to_shoot_mass_ratio	trait_0011913
Side branch dry mass to whole plant dry mass ratio	branch_mass_fraction	trait_0011914
Stem dry matter content (SDMC)	stem_dry_matter_content	trait_0011915
Stem water content per unit saturated stem mass	stem_water_content_per_saturated_mass	trait_0011916
Stem mass fraction	stem_mass_fraction	trait_0011917
Bark morphology, Eucalyptus	bark_morphology_eucalyptus	trait_0012010
Bark thickness	bark_thickness	trait_0012011
Scaled bark thickness	bark_thickness_index	trait_0012012
Bark density	bark_density	trait_0012013
Bark dry mass per unit bark surface area	bark_dry_mass_per_surface_area	trait_0012014
Bark water content per unit bark dry mass	bark_water_content_per_dry_mass	trait_0012015
Bark water content per unit saturated bark mass	bark_water_content_per_saturated_mass	trait_0012016
Root diameter	root_diameter	trait_0012111
Root system morphology	root_system_classification	trait_0012112
Fine root volume to coarse root volume ratio	root_fine_root_coarse_root_ratio	trait_0012113
Root biomass depth distribution coefficient	root_distribution_coefficient	trait_0012114
Root system type (presence of taproot)	root_system_type	trait_0012115
Specific root length (SRL)	root_specific_root_length	trait_0012116
Specific tap root length (STRL)	root_specific_taproot_length	trait_0012117

Root surface area per unit root dry mass (specific root area)	root_specific_root_area	trait_0012118
Root wood density	root_wood_density	trait_0012119
Root to shoot ratio	root_shoot_ratio	trait_0012120
Root dry matter content (RDMC)	root_dry_matter_content	trait_0012121
Root mass fraction	root_mass_fraction	trait_0012122
Seed accessory cost fraction	accessory_cost_fraction	trait_0012221
Seed accessory cost mass	accessory_cost_mass	trait_0012222
Number of androecium parts in each whorl (Androecium structural merism)	flower_androecium_structural_merism	trait_0012410
Androecium structural phyllotaxis	flower_androecium_structural_phyllotaxis	trait_0012411
Number of androecium structural whorls	flower_androecium_structural_whorls_count	trait_0012412
Anther attachment	flower_anther_attachment	trait_0012413
Connective extension (apical)	flower_anther_connective_extension	trait_0012414
Anther dehiscence	flower_anther_dehiscence	trait_0012415
Anther orientation	flower_anther_orientation	trait_0012416
Flower colour	flower_colour	trait_0012417
Perianth colour	perianth_colour	trait_0012418
Flower length	flower_length	trait_0012419
Flower diameter	flower_diameter	trait_0012420
Floral orientation	flower_orientation	trait_0012421
Maximum flower number	flower_count_maximum	trait_0012422
Number of fertile stamens	flower_fertile_stamens_count	trait_0012431
Filament presence and shape	flower_filament	trait_0012432
Fusion of filaments	flower_filament_fusion	trait_0012433
Fusion of filaments to inner perianth series	flower_filament_fusion_to_inner_perianth	trait_0012434
Gynoecium phyllotaxis	flower_gynoecium_phyllotaxis	trait_0012441
Placentation	flower_gynoecium_placentation	trait_0012442
Fusion of ovaries	flower_ovary_fusion	trait_0012443
Ovary position	flower_ovary_position	trait_0012444
Number of ovules per functional carpel	flower_ovules_per_functional_carpel_count	trait_0012445
Perianth differentiation	flower_perianth_differentiation	trait_0012461
Fusion of perianth	flower_perianth_fusion	trait_0012462
Number of perianth parts in each whorl (Perianth merism)	flower_perianth_merism	trait_0012463
Number of perianth parts	flower_perianth_parts_count	trait_0012464
Perianth phyllotaxis	flower_perianth_phyllotaxis	trait_0012465
Symmetry of perianth	flower_perianth_symmetry	trait_0012466
Number of perianth whorls	flower_perianth_whorls_count	trait_0012467
Pollen grain aperture shape	flower_pollen_aperture_shape	trait_0012471
Number of pollen grain apertures	flower_pollen_apertures_count	trait_0012472
Pollen grain length	flower_pollen_length	trait_0012473
Number of structural carpels	flower_structural_carpels_count	trait_0012481

Floral structural sex	flower_structural_sex_type	trait_0012482
Style differentiation	flower_style_differentiation	trait_0012483
Fusion of styles	flower_style_fusion	trait_0012484
Fruit dry mass	fruit_dry_mass	trait_0012511
Fruit length	fruit_length	trait_0012512
Fruit width	fruit_width	trait_0012513
Fruit breadth	fruit_height	trait_0012514
Fruit wall thickness	fruit_wall_thickness	trait_0012515
Fruit type	fruit_type	trait_0012516
Fruit fleshiness	fruit_fleshiness	trait_0012517
Fruit dehiscence	fruit_dehiscence	trait_0012518
Fruit colour	fruit_colour	trait_0012519
Seed dry mass	seed_dry_mass	trait_0012610
Diaspore dry mass	diaspore_dry_mass	trait_0012611
Seed embryo and endosperm dry mass	seed_dry_mass_reserve	trait_0012612
Seed length	seed_length	trait_0012613
Seed width	seed_width	trait_0012614
Seed height	seed_height	trait_0012615
Seed volume	seed_volume	trait_0012616
Seed count	seed_count	trait_0012617
Seed shape	seed_shape	trait_0012618
Seed surface hairs	seed_surface_hairs	trait_0012619
Seed surface texture	seed_surface_texture	trait_0012620
Seed surface reflectivity	seed_surface_reflectivity	trait_0012621
Diaspore fleshiness	diaspore_fleshiness	trait_0012622
Dispersal appendage	dispersal_appendage	trait_0012623
Dispersal unit	dispersal_unit	trait_0012624
Leaf secondary vein angle	leaf_secondary_vein_angle	trait_0013011
Major leaf vein density	leaf_major_vein_density	trait_0013012
Length of all minor and major leaf lamina veins per unit area	leaf_total_vein_density	trait_0013013
Leaf vein frequency	leaf_vein_frequency	trait_0013014
Stem xylem vessel density	stem_vessel_density	trait_0013111
Leaf xylem vessel density	leaf_vessel_density	trait_0013112
Stem xylem vessel diameter	stem_vessel_diameter	trait_0013113
Stem xylem vessel hydraulic mean diameter	stem_vessel_diameter_hydraulic	trait_0013114
Leaf xylem vessel diameter	leaf_vessel_diameter	trait_0013115
Stem xylem vessel lumen fraction	stem_vessel_lumen_fraction	trait_0013116
Stem xylem vessel multiple fraction	stem_vessel_multiple_fraction	trait_0013117
Stem non-lumen fraction	stem_vessel_non_lumen_fraction	trait_0013118
xylem vessel wall fraction	stem_vessel_wall_fraction	trait_0013119

Xylem vulnerability index	stem_xylem_vulnerability_index	trait_0013120
Wood axial parenchyma fraction	wood_axial_parenchyma_fraction	trait_0013161
Wood conduit fraction	wood_conduit_fraction	trait_0013162
Wood fibre fraction	wood_fibre_fraction	trait_0013163
Wood ray parenchyma fraction	wood_ray_parenchyma_fraction	trait_0013164
Wood tracheid fraction	wood_tracheid_fraction	trait_0013165
Leaf work to punch	leaf_work_to_punch	trait_0014011
Leaf specific work to punch	leaf_work_to_punch_adjusted	trait_0014012
Leaf work to shear	leaf_work_to_shear	trait_0014013
Leaf specific work to shear (fracture toughness)	leaf_work_to_shear_adjusted	trait_0014014
Leaf work to tear	leaf_work_to_tear	trait_0014015
Leaf specific work to tear	leaf_work_to_tear_adjusted	trait_0014016
Bark modulus of elasticity	bark_modulus_of_elasticity	trait_0014017
Stem modulus of elasticity	stem_modulus_of_elasticity	trait_0014018
Xylem modulus of elasticity	xylem_modulus_of_elasticity	trait_0014019
Modulus of rupture	modulus_of_rupture	trait_0014020
Biological Process Trait (Physiological Process Trait)		
Plant photosynthetic pathway	photosynthetic_pathway	trait_0020221
Bark photosynthesis	bark_photosynthetic_status	trait_0020222
Leaf photosynthesis rate per unit leaf area under ambient light and CO2 (A)	leaf_photosynthetic_rate_per_area_ambient	trait_0020240
Leaf photosynthesis rate per unit leaf area under saturating light and CO2 (Amax)	leaf_photosynthetic_rate_per_area_maximum	trait_0020241
Leaf photosynthesis rate per unit leaf area under saturating light and ambient CO2 (Asat)	leaf_photosynthetic_rate_per_area_saturated	trait_0020242
Leaf photosynthesis rate per unit leaf dry mass under ambient light and CO2 (A)	leaf_photosynthetic_rate_per_dry_mass_ambient	trait_0020243
Leaf photosynthesis rate per unit leaf dry mass under saturating light and CO2 (Amax)	leaf_photosynthetic_rate_per_dry_mass_maximum	trait_0020244
Leaf photosynthesis rate per unit leaf dry mass under saturating light and ambient CO2 (Asat)	leaf_photosynthetic_rate_per_dry_mass_saturated	trait_0020245
Leaf internal CO2 concentration during Amax measurement (ci)	leaf_intercellular_CO2_concentration_at_Amax	trait_0020310
Internal CO2 concentration during Asat measurement (ci)	leaf_intercellular_CO2_concentration_at_Asat	trait_0020311
Internal CO2 concentration under ambient conditions (ci)	leaf_intercellular_CO2_concentration_at_Aambient	trait_0020312
Ratio of internal to external CO2 concentrations (ci/ca)	leaf_intercellular_CO2_concentration_to_atmospheric_CO2_concentration_ratio	trait_0020313
CO2 concentration inside chloroplasts (cc)	leaf_chloroplast_CO2_concentration	trait_0020314
Ambient CO2 concentration (ca)	atmospheric_CO2_concentration	trait_0020315
Leaf Jmax per unit leaf area (Jmax)	leaf_photosynthesis_Jmax_per_area	trait_0020410
Leaf Jmax per unit leaf area at 25 deg C (Jmax25)	leaf_photosynthesis_Jmax_per_area_25C	trait_0020411
Leaf Jmax per unit leaf mass (Jmax)	leaf_photosynthesis_Jmax_per_mass	trait_0020412
Leaf Vcmax per unit leaf area (Vcmax)	leaf_photosynthesis_Vcmax_per_area	trait_0020413

Leaf Vcmax per unit leaf area at 25 deg C (Vcmax25)	leaf_photosynthesis_Vcmax_per_area_25C	trait_0020414
Leaf Vcmax per unit leaf mass (Vcmax)	leaf_photosynthesis_Vcmax_per_mass	trait_0020415
Leaf Jmax to leaf Vcmax ratio at 25 deg C	leaf_photosynthesis_Jmax_over_Vcmax_25C	trait_0020416
Leaf maximum quantum yield (Fv/Fm)	leaf_fluorescence_fv_over_fm	trait_0020417
Leaf ambient quantum yield	leaf_fluorescence_quantum_yield	trait_0020418
Leaf quantum yield, gas exchange measurement	leaf_gas_exchange_quantum_yield	trait_0020419
Leaf respiration rate per unit leaf area, in the dark (Rdark)	leaf_dark_respiration_per_area	trait_0020510
Leaf respiration rate per unit leaf dry mass, in the dark (Rdark)	leaf_dark_respiration_per_dry_mass	trait_0020511
Leaf respiration rate per unit leaf area, in the light (Rday)	leaf_light_respiration_per_area	trait_0020512
Stem respiration rate per unit stem area, in the dark	stem_dark_respiration_per_area	trait_0020513
Leaf stomatal conductance to water vapour per unit leaf area under ambient conditions (gsw)	leaf_stomatal_conductance_per_area_ambient	trait_0020610
Leaf stomatal conductance to water vapour per unit leaf area during Amax measurement (gsw)	leaf_stomatal_conductance_per_area_at_Amax	trait_0020611
Leaf stomatal conductance to water vapour per unit leaf area during Asat measurement (gsw)	leaf_stomatal_conductance_per_area_at_Asat	trait_0020612
Leaf stomatal water vapour resistance under ambient conditions	leaf_stomatal_resistance_ambient	trait_0020630
Leaf mesophyll conductance to carbon dioxide per unit leaf area (gm)	leaf_mesophyll_conductance_per_area	trait_0020640
Leaf mesophyll conductance to carbon dioxide per unit leaf mass (gm)	leaf_mesophyll_conductance_per_mass	trait_0020641
Leaf transpiration per unit leaf area under ambient conditions (E)	leaf_transpiration_per_area_ambient	trait_0020660
Leaf transpiration per unit leaf area during Amax measurement (E)	leaf_transpiration_per_area_at_Amax	trait_0020661
Leaf transpiration per unit leaf area during Asat measurement (E)	leaf_transpiration_per_area_at_Asat	trait_0020662
Leaf transpiration rate per unit leaf area, in the dark	leaf_dark_transpiration_per_area	trait_0020663
Integrated plant transpiration	integrated_plant_transpiration	trait_0020664
Whole plant sapflow	whole_plant_sapflow	trait_0020665
Leaf photosynthetic nitrogen use efficiency during Amax measurement (PNUE)	leaf_photosynthetic_nitrogen_use_efficiency_maximum	trait_0020710
Leaf photosynthetic nitrogen use efficiency during Asat measurement (PNUE)	leaf_photosynthetic_nitrogen_use_efficiency_saturated	trait_0020711
Leaf photosynthetic phosphorus use efficiency during Amax measurement PPUE)	leaf_photosynthetic_phosphorus_use_efficiency_maximum	trait_0020712
Leaf photosynthetic phosphorus use efficiency during Asat measurement (PPUE)	leaf_photosynthetic_phosphorus_use_efficiency_saturated	trait_0020713
Integrated water use efficiency	leaf_water_use_efficiency_integrated	trait_0020760
Intrinsic water use efficiency (WUEi)	leaf_water_use_efficiency_intrinsic	trait_0020761
Instantaneous water use efficiency (WUE)	leaf_water_use_efficiency_instantaneous	trait_0020762
Stem hydraulic conductivity (Kh)	stem_hydraulic_conductivity	trait_0021013
Sapwood specific hydraulic conductivity (Ks)	sapwood_specific_hydraulic_conductivity	trait_0021014
Theoretical sapwood specific hydraulic conductivity (Ks)	sapwood_specific_hydraulic_conductivity_theoretical	trait_0021015

Stem specific hydraulic conductivity (Ks)	stem_specific_hydraulic_conductivity	trait_0021016
Leaf specific hydraulic conductance (kleaf)	leaf_specific_hydraulic_conductance	trait_0021017
Leaf specific hydraulic conductivity (Kl)	leaf_specific_hydraulic_conductivity	trait_0021018
Root hydraulic conductivity (Kh)	root_hydraulic_conductivity	trait_0021021
Root specific hydraulic conductivity	root_specific_hydraulic_conductivity	trait_0021022
Pre-dawn water potential	water_potential_predawn	trait_0021030
Midday water potential	water_potential_midday	trait_0021031
Stem sapwood capacitance (C)	stem_sapwood_capacitance	trait_0021032
Leaf capacitance (Cleaf)	leaf_capacitance	trait_0021033
Root sapwood capacitance (C)	root_sapwood_capacitance	trait_0021034
Leaf xylem pressure, 50% lost conductance	leaf_hydraulic_vulnerability	trait_0021050
Stem xylem pressure, 12% lost conductivity	water_potential_12percent_lost_conductivity	trait_0021051
Stem xylem pressure, 50% lost conductivity	water_potential_50percent_lost_conductivity	trait_0021052
Stem xylem pressure, 88% lost conductivity	water_potential_88percent_lost_conductivity	trait_0021053
Hydraulic safety margin, 50%	hydraulic_safety_margin_50	trait_0021054
Hydraulic safety margin, 88%	hydraulic_safety_margin_88	trait_0021055
Leaf turgor loss point	leaf_turgor_loss_point	trait_0021056
Osmotic potential	osmotic_potential	trait_0021057
Osmotic potential at full tugor	osmotic_potential_at_full_turgor	trait_0021058
Bulk modulus of elasticity (e)	bulk_modulus_of_elasticity	trait_0021059
Leaf relative water content predawn	leaf_relative_water_content_predawn	trait_0021060
Leaf relative water content at turgor loss point	leaf_relative_water_content_at_turgor_loss_point	trait_0021061
Root xylem pressure, 50% lost conductivity	root_water_potential_50percent_lost_conductivity	trait_0021062
Photochemical reflectance index (PRI)	leaf_photochemical_reflectance_index	trait_0020813
Water band index	leaf_water_band_index	trait_0020814
Modified normalized difference vegetation index (modified NDVI)	modified_NDVI	trait_0020815
Modified chlorophyll absorption ratio index 705	leaf_chlorophyll_index_modified_ND705	trait_0020816
Life History Trait		
Plant growth form	plant_growth_form	trait_0030010
Life form	life_form	trait_0030011
Life history	life_history	trait_0030012
Ephemeral life history class	life_history_ephemeral_class	trait_0030013
Lifespan	lifespan	trait_0030014
Plant growth substrate	plant_growth_substrate	trait_0030015
Plant photosynthetic organ	plant_photosynthetic_organ	trait_0030016
Plant alternative energy and nutrient acquisition strategies	plant_alternative_energy_and_nutrient_acquisition_strategy	trait_0030017
Woodiness	woodiness	trait_0030018
Detailed woodiness categories	woodiness_detailed	trait_0030019
Physical defence structures	plant_physical_defence_structures	trait_0030020

Plant climbing mechanisms	plant_climbing_mechanism	trait_0030021
Plant succulence	plant_succulence	trait_0030022
Stem growth habit	stem_growth_habit	trait_0030023
Leaf phenology	leaf_phenology	trait_0030024
Leaf lifespan	leaf_lifespan	trait_0030025
Competitive stratum	competitive_stratum	trait_0030026
Plant nitrogen fixation capacity	nitrogen_fixing	trait_0030027
Plant root structures	root_structure	trait_0030028
Plant parasitism status	parasitic	trait_0030029
Plant sex type	sex_type	trait_0030060
Pollination syndrome	pollination_syndrome	trait_0030061
Pollination system	pollination_system	trait_0030062
Plant genome size	genome_size	trait_0030080
Chromosome ploidy	ploidy	trait_0030081
Age of reproductive maturity	reproductive_maturity	trait_0030210
Diaspore dispersal syndrome	dispersal_syndrome	trait_0030211
Diaspore dispersal agents	dispersers	trait_0030212
Environmental flowering cues	flowering_cues	trait_0030213
Flowering time, by month	flowering_time	trait_0030214
Fruiting time, by month	fruiting_time	trait_0030215
Seedling recruitment time, by month	recruitment_time	trait_0030216
Seedling establishment conditions	seedling_establishment_conditions	trait_0030217
Canopy light environment required for reproduction	reproductive_light_environment_index	trait_0030218
Canopy light environment required for seedling establishment	establishment_light_environment_index	trait_0030219
Seed storage location	seedbank_location	trait_0030411
Serotiny	serotiny	trait_0030412
Seedbank longevity class	seedbank_longevity_class	trait_0030413
Seedbank longevity	seedbank_longevity	trait_0030414
Dormancy type	seed_dormancy_class	trait_0030415
Seed germination treatment	seed_germination_treatment	trait_0030416
Seed germination proportion	seed_germination	trait_0030417
Seed viability	seed_viability	trait_0030418
Seed germination time	seed_germination_time	trait_0030419
Vegetative reproduction ability	vegetative_reproduction_ability	trait_0030510
Clonal spread mechanism	clonal_spread_mechanism	trait_0030511
Storage organ	storage_organ	trait_0030512
Bud bank location	bud_bank_location	trait_0030513
Sprout depth	sprout_depth	trait_0030514
Post-fire resprouting capacity	resprouting_capacity	trait_0030610
Post-fire proportion resprouting individuals	resprouting_capacity_proportion_individuals	trait_0030611
Post-fire resprouting capacity of juvenile plants	resprouting_capacity_juvenile	trait_0030612

Time from seedling germination until individuals survive a fire	resprouting_capacity_time_from_germination	trait_0030613
Post-fire to pre-fire stem ratio	resprouting_capacity_stem_ratio	trait_0030614
Plant vegetative response to disturbances other than fire	resprouting_capacity_non_fire_disturbance	trait_0030615
Fire exposure level	fire_exposure_level	trait_0030651
Post-fire recruitment	post_fire_recruitment	trait_0030652
Post-fire flowering	post_fire_flowering	trait_0030653
Time from fire to first flowering	fire_time_from_fire_to_flowering	trait_0030654
Time from fire until 50% of individuals are flowering	fire_time_from_fire_to_50_percent_flowering	trait_0030655
Time from fire to peak flowering	fire_time_from_fire_to_peak_flowering	trait_0030656
Time from fire until flowering declines	fire_time_from_fire_to_flowering_decline	trait_0030657
Time from fire to fruiting	fire_time_from_fire_to_fruiting	trait_0030658
Time from fire until 50% of individuals are fruiting	fire_time_from_fire_to_50_percent_fruiting	trait_0030659
Fuel bed bulk density	fire_fuel_bed_bulk_density	trait_0030710
Fuel consumption by fire	fire_fuel_consumption	trait_0030711
Fire rate of spread	fire_rate_of_spread	trait_0030712
Leaf smoulder duration	fire_smoulder_duration	trait_0030713
Leaf flame duration	fire_flame_duration	trait_0030714
Leaf flame and smoulder duration	fire_total_burn_duration	trait_0030715
Fire time to ignition	fire_time_to_ignition	trait_0030716
Plant resource requirements and tolerance	plant_type_by_resource_use	trait_0030810
Plant flood regime response	plant_flood_regime_classification	trait_0030811
Plant water-logging tolerance	plant_tolerance_water_logged_soils	trait_0030812
Plant inundation tolerance	plant_tolerance_inundation	trait_0030813
Plant snow tolerance	plant_tolerance_snow	trait_0030814
Plant soil salinity tolerance	plant_tolerance_soil_salinity	trait_0030815
Plant salt tolerance strategy	plant_tolerance_salt	trait_0030816
Plant calcium sensitivity	plant_tolerance_calcicole	trait_0030817
Plant fire tolerance strategy	plant_tolerance_fire	trait_0030818

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711 **Supplementary Table 4.** Columns in the data table APD_traits.csv

Column(s)	Description
identifier	IRI for trait within APD schema
trait	Alternate label for trait within APD schema
label	Label for trait within APD schema
description_encoded	Description of trait, with key words linked to terms from published vocabularies/ontologies
description	Description of trait
comments	Additional comments about the trait, including possible sources of error, related traits, or best-practise methodologies
inScheme	Indication that this term is within the ADP schema
type	Indicating whether this is a categorical or numeric trait, by linking to the appropriate term within the STATO ontology
type_x	String indicating whether this is a categorical or numeric trait
min	For numeric traits, the minimum allowable value
max	For numeric traits, the maximum allowable value
units	For numeric traits, the standard units for this trait within APD
units_UCUM	For numeric traits, the UCUM syntax for the standard units
units_uom	For numeric traits, the units of measurement syntax for the standard units
category_1, category_2, category_3, category_4	Up to four columns indicating hierarchical categories into which the trait is mapped
created	Date the trait was first created
modified	Date the trait was most recently modified
deprecated_trait_name	Previous labels used for this trait concept
constraints	The scope of the trait, indicating taxonomic groups for which the trait is used or if the trait only applies to taxa with specific morphologies
structure_1, structure_2, structure_3, structure_4	Up to four columns indicating the plant structure (a tissue, organ, or the whole plant) that is measured by this trait
meas_char_1, meas_char_2, meas_char_3, meas_char_4, meas_char_5, meas_char_6	Up to six columns indicating the characteristic that is measured, such as whether the trait records `mass`, `shape`, `length`, etc.

rev_01, rev_02, rev_03, rev_04, rev_05, rev_06, rev_07, rev_08, rev_09, rev_10	Up to ten columns indicating people who have reviewed this trait concept
ref_1, ref_2, ref_3, ref_4, ref_5	Up to five columns indicating references linked to this trait concept
keyword_1, keyword_2, keyword_3, keyword_4, keyword_5, keyword_6, keyword_7, keyword_8, keyword_9, keyword_10	Up to ten columns indicating keywords linked to this trait concept; the keywords are generally terms in published vocabularies
exact_other1, close_other1, close_other2, related_other	Formally published vocabularies/ontologies with traits that are identical, similar, or related to this trait concept.
exact_TOP, close_TOP, related_TOP, related_TOP2	Traits within the TOP Trait Thesaurus that are identical, similar, or related to this trait concept.
exact_TRY, close_TRY, related_TRY	Traits within the TRY Plant Trait Database that are identical, similar, or related to this trait concept.
exact_LEDA, close_LEDA, related_LEDA	Traits within the LEDA Database that are identical, similar, or related to this trait concept.
exact_GIFT, close_GIFT, related_GIFT	Traits within the GIFT Database that are identical, similar, or related to this trait concept.
exact_BIEN, close_BIEN, related_BIEN	Traits within the BIEN Database that are identical, similar, or related to this trait concept.
exact_BROT, close_BROT, related_BROT	Traits within the BROT Database that are identical, similar, or related to this trait concept.
PalmTraits_exact, PalmTraits_close	Traits within the PalmTraits Database that are identical or similar to this trait concept.

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715 **Supplementary Table 5.** Columns in the data table APD_references.csv

Column	Description	Annotation Property*
Entity	URL for reference, if available	
label	Author-year label for reference	skos:label
citation	Full reference citation	dcterms:bibliographicCitation
identifier	Identifier for reference, a DOI when available, or otherwise an ISBN (for books) or URL (for websites)	dcterms:identifier
title	The title of the reference	dcterms:title

716 * See Table 3 footnotes for the full schema URL's associated with each annotation property
717 prefix.

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720 **Supplementary Table 6**. Columns in the data table APD_reviewers.csv

Column	Description	Annotation Property*
Entity	URL for the reviewer's ORCID profile	
label	Reviewer's full name	skos:label
ORCID	Reviewer's ORCID number	obo:IAO_0000708 (ORCID identifier)

721 * See Table 3 footnotes for the full schema URL's associated with each annotation property
722 prefix.

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725 **Supplementary Table 7**. Columns in the data table APD_units.csv

Column	Description	Annotation Property*
Entity	Units of Measurement IRI for the specific units of measurement	
label	Label for these units of measurement	skos:label
altLabel	Alternative written label for these units of measurement	skos:altLabel
description	Verbal description of these units of measurement	dcterms:description
SI_code	The International System of Units code for these units of measurement	uom:SI_code
UCUM_code	The Unified Code for Units of Measure code for these units of measurement	uom:UCUM_code
exactMatch	Up to 6 columns indicating exact matches for this unit of measurement in other ontologies	skos:exactMatch

726 * See Table 3 footnotes for the full schema URL's associated with each annotation property
727 prefix.

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730 **Supplementary Table 8**. Columns in the data table published_classes.csv

Column	Description	Annotation Property*
Entity	URI for a specific term (class) in a published ontology	
label	Label for the term	skos:label
description	Verbal description of the term	dcterms:description
identifier	Identifier for the term within a specific vocabulary	dcterms:identifier
inScheme	URI for the vocabulary in which the term is published	skos:inScheme
prefix	Prefix for the specific vocabulary	(Not used)
vocabulary	Name of the specific vocabulary	(Not used)

731 * See Table 3 footnotes for the full schema URL's associated with each annotation property
732 prefix.

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735 **Supplementary Table 9**. Columns in the data table APD_categorical_values.csv

Column	Description	Annotation Property*
identifier	Identifier for a specific categorical trait value within APD	dcterms:identifier
label	Label for the categorical trait value	skos:label
description	Description of the categorical trait value	dcterms:description
trait_name	Trait name to which the categorical trait value refers	skos:broader

736 * See Table 3 footnotes for the full schema URL's associated with each annotation property
737 prefix.

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740 **Supplementary Table 10**. Columns in the data table APD_trait_hierarchy.csv

Column	Description	Annotation Property*
Entity	URI for a trait category (hierarchical level) within APD	
label	Label for a trait category (hierarchical level) within APD	skos:label
description	Description of a trait category (hierarchical level) within APD	dcterms:description
Parent	Superclass (higher hierarchical level) for a trait category within APD	skos:broader
exactMatch	Link to identical concept in a published ontology	skos:exactMatch
tier_1	Highest hierarchical level into which the category fits	(Not used)
tier_2	Second highest hierarchical level into which the category fits	(Not used)
tier_3	Third highest hierarchical level into which the category fits (if applicable)	(Not used)
tier_4	Fourth highest hierarchical level into which the category fits (if applicable)	(Not used)
hierarchy	Written string indicating the full hierarchy of the specific category	(Not used)

741 * See Table 3 footnotes for the full schema URL's associated with each annotation property
742 prefix.

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745 **Supplementary Table 11.** Columns in the data table APD_glossary.csv

Column	Description	Annotation Property*
identifier	Identifier for a specific glossary term within APD/glossary	dcterms:identifier
label	Label for the glossary term	skos:label
description	Description of the glossary term	dcterms:description

746 * See Table 3 footnotes for the full schema URL's associated with each annotation property
747 prefix.

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Supplementary Table 12. Columns in the data table APD_annotation_properties.csv

Column	Description	Annotation Property*
Entity	URI for annotation properties used by the APD	
label	Label for annotation properties used by the APD, from its own vocabulary	skos:label
description	Description of annotation properties used by the APD, from its own vocabulary	dcterms:description
issued	Date a term was issued within its vocabulary	dcterms:issued
comment	Additional comments about annotation properties used by the APD, from its own vocabulary	rdfs:comment
isDefinedBy	URI for the vocabulary in which the term is published	rdfs:isDefinedBy
inScheme	URI for the vocabulary in which the term is published	skos:inScheme

* See Table 3 footnotes for the full schema URL's associated with each annotation property prefix.

755 **Supplementary Table 13**. Columns in the data table APD_namespace_declaration.csv

Column	Description	Annotation Property*
prefix	Prefix used for a specific vocabulary within APD machine-readable representations	
Scheme	URI for each vocabulary used in the APD	skos:inScheme

756 * See Table 3 footnotes for the full schema URL's associated with each annotation property
757 prefix.

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760 **Supplementary Table 14**. Columns in the data table APD_resource.csv

Column	Description
Subject	Entity URI for the APD schema
Predicate	Annotation properties for the APD schema
Object	Value of a particular annotation property for the APD schema

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