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Automated taxonomic descriptions

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Abstract

Automation of taxonomic descriptions has progressed to the extent that several large-scale, functional accounts operable from microcomputers are now available. They permit automated generation of typeset and microfiche descriptions and keys, which are readily updated and relatively easily translated into different natural languages. They also permit direct information retrieval, are conveniently accessible for classificatory experiments, and provide online identificatory facilities superior to printed keys (extending, for example, the possibilities for identifying fragmentary material). Their general applicability and present capabilities are illustrated by applications of the DELTA system to the genera of grasses and legumes, plant viruses, species of beetles, and a floristic account of the Paniceae of Australia.

Introduction

We illustrate here the versatility and practicability of methods for preparing and using automated taxonomic descriptions, with reference to fully operational sets of data which are available to potential users. The given examples are all organized under the DELTA system (Dallwitz 1980a; Dallwitz and Paine 1986), which is itself freely available accompanied by a small, operational set of data, working examples of all directives files, and a 'Primer' (Partridge et al. 1986). DELTA was designed to satisfy the need for a generalized system capable of accommodating all the different kinds of descriptive data used by taxonomists, without information loss, in an easy-to-use format chosen to minimize coding errors; and for facilities to translate data into the diversity of special formats required by programs (e.g. KEYGEN, Pankhurst 1970; MULTBET, Lance and Williams 1967) for classification and identification (cf. Watson and Milne 1972; Clifford and Watson 1977).

DELTA in its present form handles unordered and ordered multistate (including two-state) characters, counts, measurements, and text. Intermediates, ranges, combinations, and alternatives can be represented in a natural way, and distinction is made between 'variable', 'unknown', and 'inapplicable'. With all character types, comments can be used to qualify or amplify the coded information. An associated program, CONFOR, translates the coded descriptions into natural language, offering a choice of formats; produces summarized descriptions of specified sets of taxa, giving numbers of taxa exhibiting each character state and for numeric characters giving means, ranges, and the names of taxa representing the extremes of ranges; and carries out various data maintenance operations — for example, changing the sequences of characters and character states, while automatically keeping all the files consistent with one another. Data coded in DELTA format can also be translated into the formats used by various other taxonomic programs, of which the following are currently available via CONFOR:

KEY. Generation of tabular and sequential printed keys (Dallwitz 1974; Dallwitz and Paine 1986).
PABTRAN. Punched card keys (Higgins 1979).
DCR. The TAXON numerical taxonomy package developed by CSIRO Division of Computing Research (Ross et al. 1985).
GENKEY. Key generation (Payne 1975).
EXIR/TAXIR. Information retrieval (Estabrook and Brill 1969).

DIST. Generation of distance matrices (M. J. Dallwitz and T. A. Paine unpubl.).
PAUP. Phylogenetic analysis (Swofford 1984).
INTKEY. Interactive identification and information retrieval (M. J. Dallwitz and T. A. Paine unpubl.)

DELTA format is used directly by programs of the PANKEY package for key generation, interactive key construction, polyclaves, interactive identification, identification by matching, description printing, and diagnostic descriptions (Pankhurst 1970, 1975, 1978a,b, 1983, 1986; Pankhurst and Aitchison 1975; Dallwitz and Paine 1986, Appendix 4). Of particular interest are the programs for interactive identification, ONLINE and INTKEY. These are similar in many ways to an ‘expert system’. The latest version of ONLINE includes colour graphics, and was demonstrated at the meeting using a data set for British orchids with leaf and flower characters illustrated by high resolution colour drawings.

The appended examples, and the publications associated with them, demonstrate the applicability of DELTA at different levels of the taxonomic hierarchy, to prepare and present printed descriptions and keys. They also illustrate its ability to cope with diverse materials (flowering plants, beetles, viruses). Automation can streamline the exacting and time-consuming operations which have always been required by taxonomic work, and facilitates operations which surely would long have been routine had they been practicable. It also provides access to novel taxonomic services, in the form of interactive facilities. The advantages may be summarized as follows.

1. Convenient access to data for making corrections and additions, in order to keep descriptions, keys, and classifications up to date.
2. Ease of applying a diversity of classificatory techniques to any group for which data are available, and ease of obtaining fully comparative subgroup descriptions.
3. Ease of extracting descriptions and keys for specified subsets of taxa and characters, to prepare regional accounts, special purpose keys, etc. Printed keys thus produced are structured especially for the sets of taxa included, and are more efficient than hand-made equivalents adapted from other keys.
4. Ready access to superior identificatory aids, including punchcard keys and interactive identification. Apart from their superiority over printed keys for routine identification, these greatly extend the possibilities for identifying fragmentary material.
5. Easy, rapid retrieval of information, for example, to obtain lists of taxa unrecorded for particular characters; to prepare lists of taxa exhibiting or lacking particular features, when seeking geographical patterns and correlations with ecological or physiological observations; in checking the credentials and relationships of ostensibly new taxa (e.g. Lazarides and Watson 1986); in helping define appropriate samples for experimental work (see Example 7).
6. The relative ease of translating basic descriptions and derivative keys, etc., into different natural languages, calling for translation of only the character list.
7. Direct links with automatic typesetting and fiche generation, facilitating circulation of up-to-date information while minimizing proof-reading and publication costs.

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Examples

These sample descriptions and key (Examples 1–6) exemplify CONFOR and KEY output, reproduced without subsequent editing. They have been automatically typeset on a III COMp80 phototypesetter, using the program TYPSET (Dallwitz 1980b). Each complete data set is available on magnetic tape, or on MS-DOS discs. They can all be processed by CONFOR and employed for interactive identification via the programs ONLINE (Pankhurst 1978a) and INTKEY using MS-DOS microcomputers. All other operations can also be run on microcomputers using the smaller data sets, or subsets of the large sets. Example 7 shows use of ONLINE for a purpose other than that for which it was primarily intended.

Example 1. The genera of Leguminosae-Caesalpiniodeae

One of 177 generic descriptions, prepared, maintained by and obtainable from Watson (Watson 1981; Watson and Dallwitz 1983).

Caesalpinia L. Tropical and sub-tropical, 100 species

Habit and leaf form. Trees, or shrubs, or herbs, or climbers or scramblers; without tendrils; armed (with prickly branchlets and rachides), or unarmed. Leaves and inflorescences crowded on short shoots, or not crowded on short shoots. Phyllotaxy spiral. Leaves compound; pinnate (rarely, in Chile and Cuba; = *Balsamocarpon*), or bipinnate; with opposite or sub-opposite pinnae; with opposite or sub-opposite leaflets, or with alternate leaflets; paripinnate; with rachides adaxially ridged. Leaflets many per leaf, or few per leaf; with markedly twisted petiolules, or with petiolules not noticeably twisted. Stipules absent or early caducous or very inconspicuous, or present, persistent and conspicuous; leafy, or spinescent, or neither leafy nor spinescent. Stipels present, or absent.

Inflorescence and floral morphology. Flowers small, or large and showy; hermaphrodite; pentamerous; coloured; in panicles (of racemes); not distichous. Inflorescences axillary, or terminal. Inflorescence of racemose units. Bracts absent at anthesis, or persistent beyond anthesis. Bracteoles absent. Hypanthium present. Length of floral tube relative to total hypanthium plus calyx length, about 0.25. Calyx polysepalous; covering the rest of the flower in bud, or not covering the rest of the flower in bud; markedly zygomorphic; 5 partite (the lowest tooth outside); imbricate. Corolla present; slightly zygomorphic, or very zygomorphic; polypetalous; without greatly reduced petals. Petals yellow, or red; 5; imbricate; imbricate-ascending. Clawed petals present. Disk absent. Androecium of ten parts; members all free of one another; without staminodia. Fertile stamens 10. Anthers attached well above base of connective. Dehiscence introrse; longitudinal. Ovary sessile or subsessile; free. Stigma not peltate (the style filiform). Ovules few, or numerous, or solitary.

Fruit, seed and seedling. Fruit a two-valved pod, or indehiscent (sometimes spiny); not becoming woody; straight, or distinctly curved; not internally septate; not winged; without markedly twisting or enrolling valves. Seeds endospermic, or non-endospermic; with a straight or slightly oblique radicle; amyloid-negative; with galactomannan. Cotyledons flat; Type 2, or Type 3, or Type 4; with a vascular system in one plane; epigeal, or hypogeal.

Transverse section of lamina. Leaves without conspicuous phloem transfer cells in the minor veins. Druses common in the mesophyll. Mesophyll secretory cavities (gland-dots) common, or absent; when present, without a lining of epithelium. Adaxial hypodermis absent. Leaf girders absent or very rare (the veins embedded). Laminae dorsiventral. Mesophyll without unaligned fibres or sclereids. Minor veins with no or very scanty accompanying fibrous tissue.

Leaf lamina epidermes. Epidermal crystals not seen either adaxially or abaxially. Simple unbranched hairs common, or not seen; when present scabrid, or smooth. No compound or branched eglandular hairs seen. Capitate glands present, or not seen. Hooked hairs not seen. Cassieae-type leaf pseudo-glands not seen. Expanded and embedded hair-feet absent. Adaxial interveinal epidermal cell walls straight in optical section, or markedly sinuous in high-focus optical section; conspicuously pitted, or not conspicuously pitted. Stomata adaxially common and widespread, or adaxially very rare. Abaxial stomata predominantly paracytic, or not predominantly paracytic. Abaxial epidermis not papillate. Abaxial interveinal epidermal cell walls straight, or gently undulating; conspicuously pitted in optical section, or not conspicuously pitted in optical section; scarcely staining with safranin; medium-thin.

Wood anatomy. Wood without septate fibres; storied, or not storied; without normal intercellular canals; without traumatic canals. Intervascular pits very small, or medium to large.

Pollen ultrastructure. Tectum punctate (rarely), or reticulate; smooth punctate, or puncticulate; strongly irregularly coarse-reticulate. Length of colpi greater than one half pole to pole distance (with a margocolpus). Foot layer of pollen wall with obvious projections.

Cytology, cultivation. Basic chromosome number, x = 12. Widely cultivated.

Tribe. Caesalpinieae.

Not coded: 14 16–17 22 36–38 59 71 74–75 79 110

Example 2. World grass genera

Portion of one of 761 generic descriptions, from data gathered by Watson and collaborators. Database maintained by and obtainable from Watson (Watson and Dallwitz 1981, 1985; Watson et al. 1985, 1986; Watson 1987).

Neurachne R.Br.

References. S.T. Blake 1972; (for leaf anatomy and photosynthetic pathways) Hattersley et al 1982, Hattersley and Roksandic 1983.

Habit, vegetative morphology. Perennial; caespitose (from short rhizomes). Culms 15 to 50 cm high; herbaceous. Nodes hairy, or glabrous. Culm internodes solid. Young shoots extravaginal and intravaginal (primary shoots extravaginal, each terminating in a tuft of intravaginal culm shoots). Leaves mostly basal; without auricles. Leaf blades linear (to very narrowly so); narrow; 0.9 to 3.5 mm wide; not setaceous; flat, or rolled; without readily visible transverse veins; not disarticulating; rolled in bud. Adaxial ligule a fringe of hairs.

Reproductive organization. Plants bisexual, with bisexual spikelets; with hermaphrodite florets. The spikelets of sexually distinct forms on the same plant (the lowermost being reduced).

Inflorescence. Inflorescence a single spike (almost, in *N. munroi*), or a single raceme (spike-like, or even capitate to ovoid in *N. alopecuroidea* and *N. minor*); espatheate. Spikelet-bearing axes persistent. Spikelets solitary; not secund; not two-ranked (spiralled). The spikelets subsessile to having pedicellate spikelets. Pedicel apices oblique, or discoid, or cupuliform.

Female-sterile spikelets. Several of the lowermost spikelets generally much reduced, closer together and more persistent.

Female-fertile spikelets. Spikelets 5 to 13 mm long (erect); abaxial; compressed dorsiventrally; falling with the glumes; without an apically prolonged rachilla. Hairy callus present (with very conspicuous long white hairs).

Glumes two; more or less equal; long relative to the adjacent lemmas (exceeding them); dorsiventral to the rachis; hairy (especially marginally); pointed (acuminate); awned, or awnless; very dissimilar to similar (both rigidly membranous, ovate-acuminate to lanceolate-subulate, becoming hardened towards the base. The lower ciliate or not, the upper with a dense narrow sub-marginal beard of long white hairs on each side below). Lower glume 3 to 7 nerved. Upper glume 7 to 13 nerved. Spikelets with incomplete florets. The incomplete florets proximal to the female-fertile florets. Proximal incomplete florets 1; paleate; with the palea fully developed (except occasionally in *N. alopecuroidea*); male. The proximal lemmas awnless; …

Example 3. Canadian grass genera

Descriptions in English and French of 109 genera, derived with some modifications from Example 2. This sample of part of the French version represents another of the output formats available from CONFOR, in which the numbers in parenthesis cross-reference with the character list. Available from S. G. Aiken, National Museums of Canada, Ottawa, Ontario Canada, K1A OM8 (Watson et al. 1986).

Festuca <L.> <Plus de 170, régions tempérées du monde entier et montagnes, environ 20 au Canada.>

Port, caractères végétatifs. (2) Plantes vivaces. (3) Hélophytes <rarement>; ou mésophytes; ou xérophytes. (7) À longs rhizomes; ou à longs stolons; ou à port cespiteux; ou à port décombant. (10) Chaume herbacé. (14) Hauteur du chaume à maturité 2 à 200 cm. (15) Jeunes pousses extravaginales; ou jeunes pousses intravaginales. (16) Chaume non ramifié végétativement dans la partie supérieure. (18) Chaume tubéreux à la base; ou chaume non …

Example 4. The Australian Paniceae (Poaceae)

Descriptions of 177 species, subspecies and varieties, prepared by R. D. Webster for the *Flora of Australia*. The two samples illustrate applications with synonymy and Latin diagnoses. Available from Webster (U.S.D.A., Bldg. 265, BARC East, Beltsville, Maryland, U.S.A.) or from Watson (Webster 1987).

Yakirra australiensis (Domin) Lazarides & R. Webster var. ***australiensis***, Brunonia 7(2): 293 (1985). — *Ichnanthus australiense* (Domin) Hughes, Kew Bull. 1923: 329 (1923). — *Panicum australiense* Domin, J. Linn. Soc. (Bot.) 41: 271 (1912); Lazarides, Aust. J. Bot. 7(3): 333 (1959), *p.p.*. — Type: Western Australia, between the Ashburton and Yule Rivers, *Clement s.n.* (K, holo).

Panicum pauciflorum var. *fastigiatum* Benth., Fl. Austral. 7: 483 (1878). — Type: upper Victoria River, *Mueller s.n.* (K, iso).

Plants annual, or perennial; rhizomes absent; stolons absent. *Cataphylls* absent. *Flowering culms* erect; clumped; 5–30 cm tall (rarely to 35 cm); copiously branched; 5–10 noded. Nodes hairy (occasionally with a few scattered hairs), or glabrous. *Mid-culm internodes* solid or spongy; glabrous, or scabrous; shorter than the associated leaf sheaths. *Mid-culm leaves* with neither sheath nor blade auricles. *Mid-culm sheaths* rounded on the back; hairy; with non-ciliate …

…

(Variant) ***Y. australiensis*** var. ***intermedia*** R. Webster, *var. nov.*

Planta annua, culmis floriferis 15–35 mm altis, copiose ramosis. Foliorum ligula 0.5–1.0 mm longa; lamina 30–70 mm longa, 0.5–4 mm lata. Inflorescentia intoto vel exparte exserta; ramis primariis patentibus, 20–40 mm longis. Spiculae 3.2–3.9 mm longae, 1–1.3 mm latae; gluma inferior 1.7–2.4 mm long, 5-nervis; gluma superior 3.2–3.9 mm longa, 7-nervis; lemma inferius 3.2–3.8 mm longum, 7-nerve; lemma superius 2.3–3.7 mm longum. — Typus. Western Australia, Near Lucky Hill 23 km NNE of Dunham River, *M. Lazarides 8547* (CANB, holo).

Plants annual. *Flowering culms* 15–30 cm tall (–35 cm); copiously branched. Ligule 0.5–1 mm long. *Mid-culm leaf blades* 30–70 mm long; 0.5–4 mm wide.

Inflorescence not fully exserted. *Primary branches* spreading; 20–40 mm long.

Spikelets 4–7 on a typical lowermost primary branch; 3.2–3.9 mm long; 1–1.3 mm wide. *First glume* 1.7–2.4 mm long; 3–5 nerved. *Second glume* 3.2–3.9 mm long; 7 nerved. *Lower lemma* 3.2–3.8 mm long; 7 nerved. *Upper lemma* 2.3–3 mm long.

Western Australia, Northern Territory, and Queensland. Geobotanical distribution: Kimberley, Arnhem, Carpentaria, and Barkly. Distribution by vegetation region: tropical and subtropical sub-humid woodlands, arid and semi-arid low woodlands, arid hummock grasslands, and tropical sub-humid grasslands.

Intermediate in appearance between *Y. australiensis* var. *australiensis* and *Y. pauciflora*. Generally more profusely branched and with smaller spikelets than *Y. pauciflora*, while the more exserted inflorescence and the spreading primary branches separate it from var. *australiensis*.

Representative specimens: W.A.: Bindoola Creek, *M. Lazarides 8624* (CANB); 5 km N of Point Coulomb, *K.F. Kenneally 5905* (CANB, PERTH); Camballin, *Y. Power 799* (PERTH). N.T.: 20.8 miles W of Invervay, *G. Chippendale 5951* (CANB); near Echo Waterhole, *R. Pullen 9228* (CANB). Qld.: 25 mile hut on Normanton-Croydon road, *H.G. Bishop 264* (BRI).

Not coded: 196 200

Example 5. Plant viruses

Portion of one of over 500 plant virus descriptions. Complete for those of legumes (about 150) and for those of Australian plants; being extended to cover all plant viruses, commencing with those of tropical crops. Data provided by over 300 international contributors; organized and maintained by, and available from Gibbs and coworkers (Boswell and Gibbs 1983, 1986; Boswell *et al.* 1986).

Kennedya yellow mosaic tymovirus

INTRODUCTION. First found in *Kennedya rubicunda*. Reported in 1975 from Murrays Beach, Jervis Bay, in Australia. Dale *et al.* (1975, 1976); Gibbs (1978). Strains: Port Douglas (Mount Jukes), Jervis Bay, Wapengo; these are the type members of three geographically separate strains found in north Queensland, central coast N.S.W. and south coast N.S.W. respectively.

Data collated by A.J. Gibbs, 1981, Australia. Revised 1985.

MORPHOLOGY OF PARTICLES. Isometric; not enveloped; 28 nm in diameter; profiles rounded; capsomere arrangement readily discernible. Leaf sap contains many particles.

STABILITY IN SAP. Thermal inactivation point 65–70 °C. Longevity in vitro 10–100 days. Dilution end point 10^{-5} to 10^{-6}. Infectivity of sap not changed by treatment with di-ethyl ether.

GEOGRAPHICAL DISTRIBUTION. Spreads in coastal eastern Australia.

HOST DATA.

Natural host species and symptoms:

Kennedya rubicunda, *Desmodium triflorum*, *D. scorpiurus*, *Indigofera australis* - bright blotchy yellow mosaic. Symptoms shown by naturally infected plants persist (and are often bright).

Diagnostic host species and symptoms:

Glycine max - chlorotic local lesions, bright yellow blotchy systemic mosaic.
Kennedya rubicunda - chlorotic local lesions, systemic yellow mosaic.
Phaseolus vulgaris cv. Redland Pioneer - chlorotic local lesions; systemic yellow mosaic.
Pisum sativum - chlorotic local lesions; systemic yellow mosaic.
Vigna radiata - necrotic lesions; systemic leaf shape distortion.
Datura stramonium - chlorotic local lesion; not systemic.
Nicotiana glutinosa - chlorotic local lesions; not systemic.

Diagnostically insusceptible: *Lycopersicon esculentum*, *Nicotiana clevelandii*.

Maintenance and propagation host species: *Pisum sativum* cv. Early Massey, *Glycine max*.

Species for *L*ocal lesion or *W*hole plant assay: *Phaseolus vulgaris* cv. Redland Pioneer (L), *Pisum sativum* cv. Massey (W), *Vigna radiata* (L).

HOST PLANTS. Experimental host range narrow. Species are recorded as **S**usceptible or **I**nsusceptible to infection by any means. **Dicotyledons:** *Cajanus cajan* (S); *Chenopodium amaranticolor* (I); *Chenopodium quinoa* (I); *Clitoria ternatea* (S); *Cucumis sativus* (I); *Datura stramonium* (S); *Glycine max* (S); *Gomphrena globosa* (I); *Lotus corniculatus* (I); *Lupinus angustifolius* (S); *Lycopersicon esculentum* (I); *Macrotyloma uniflorum* (S); *Medicago sativa* (I); *Nicotiana clevelandii* (I); *Nicotiana glutinosa* (S); *Phaseolus vulgaris* (S); *Pisum sativum* (S); *Trifolium incarnatum* (I); *Trifolium pratense* (I); *Trifolium repens* (I); *Vicia faba* (I); *Vicia sativa* (I); *Vigna angularis* (S); *Vigna radiata* syn. *Phaseolus aureus* (S); *Vigna unguiculata* syn. *sinensis* (S); *Vigna unguiculata* ssp. *sesquipedalis* (S).

Sources of host range data: Dale et al. (1976); Gibbs (1978) unpublished data.

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Gibbs *et al.* (1979). *Aust. Pl. Path. Newsl.* 8: 49.

Example 6. The genus Colpochila (Coleoptera: Scarabaeidae: Melalonthinae)

Part of key a generated from descriptions of the 127 species. Prepared by and available from E. B. Britton, CSIRO Division of Entomology, G. P. O. Box 1700, Canberra, A. C. T. Australia (Britton 1986).

1(0). Lateral margins of pronotum granular and with numerous setae. 2
Lateral margins of pronotum not granular and with a single row of setae. 49
2(1). Number of antennal segments 9. 3
Number of antennal segments 8. 48
3(2). Number of lamellae in antennal club 3. 4
Number of lamellae in antennal club 4. 29
Number of lamellae in antennal club 5. 36
Number of lamellae in antennal club 6. 45
Number of lamellae in antennal club 7. ..... **carnabyi**, sp. nov. (p. 37)
4(3). Frons with setae on anterior middle and above eyes. 5
Frons with 1 or more setae above eyes only. 7
Frons without setae. 23
5(4). Pronotum surface partly or wholly clothed with long soft yellowish setae; basal margin of clypeus with a slight ridge. 6
Pronotum surface without setae, or uniformly clothed with very short setae; basal margin of clypeus with a strong ridge or declivity. ..... **aquila**, sp. nov. (p. 29)
6(5). Notch at apex of anterior angle of mentum absent; surface of elytra without setae. ..... **regia**, sp. nov. (p. 74)
Notch at apex of anterior angle of mentum present; surface of elytra with long setae near base. ..... **leo**, sp. nov. (p. 56)
7(4). Anterior margin of pronotum with setae; posterior margin of pronotum with setae. 8
Anterior margin of pronotum without setae; posterior margin of pronotum without setae or with very short fine setae. ..... **punctulata** Blanchard (p. 73)
8(7). Pronotum surface partly or wholly clothed with long soft yellowish setae. 9
Pronotum surface without setae, or uniformly clothed with very short setae. 10
9(8). Clypeus outline strongly tapered; pronotum surface dull; terminal segment of maxillary palp short; ratio length/width 2.3–2.8/1. ..... **crassiventris** Blanchard (p. 40)
Clypeus outline semielliptical slightly tapered; pronotum surface shining; terminal segment of maxillary palp elongate, ratio length/width 4.4–5.0/1. ..... **regia**, sp. nov. (p. 74)
10(8). Surface of elytra with long setae near base. 11
Surface of elytra with sparse setae on disc and apical declivity. ..... **mixta** (Lea) (p. 60)
Surface of elytra without setae. 13
11(10). Notch at apex of anterior angle of mentum absent; clypeus outline semicircular. 12
Notch at apex of anterior angle of mentum present; clypeus outline strongly tapered. ..... **chinnicki**, sp. nov. (p. 38)

Example 7. On-line assistance with experimental sampling

(A) A plant pathologist wants a list of C_4 NADP-ME grasses, possessed of certain other characteristics demanded by his equipment and working conditions. Using a set of grass generic descriptions (see Example 2) in association with the interactive identificatory program ONLINE (Pankhurst 1978a), we find (user's responses in bold face):

```
: auto 0
: exclude i u
 744 TAXA REMAIN
: 275
CHARACTER 275: photosynthetic pathway
     1 C4
     2 C3
: 1
 307 TAXA REMAIN
```

```
: 276
CHARACTER 276: C4 biochemical type as determined by enzyme assay
     1 PCK
     2 NAD-ME
     3 NADP-ME
: 3
  25 TAXA REMAIN
```

(B) We are not attempting an identification here, so the program is set (*exclude i u*) to exclude taxa for which any particular character is unknown or inapplicable; and *auto 0* overrides calculation of 'best' characters (an identificatory aid). We see that of the 744 genera in the data bank, 307 are known to consist of or include C_4 species. Of these, 25 contain species which have been typed biochemically as NADP-ME. Our physiologist's gas exchange experiments involve use of a leaf chamber, calling for a fairly large leaf area, and he sees experimental advantages in plants with a relatively short generation time:

```
: 29
CHARACTER 29: whether maximum leaf blade width exceeds 1cm
     1 leaf blades broad maximum (flattened) width greater than 1cm
     2 leaf blades narrow maximum (flattened) width no more than 1cm
: 1
  14 TAXA REMAIN
: 2
CHARACTER 2: longevity of plants
     1 annual or biennial without remains of old sheaths or culms
     2 perennial with remains of old sheaths or culms
: 1
  11 TAXA REMAIN
```

Sadly, his establishment is short of funds, and the genetic engineers have priority over glasshouses and growth cabinets. He will have to grow his material outside:

```
: 324
CHARACTER 324: geographical occurrence, in Australasian terms
     1 Tasmania
     2 New South Wales
     3 Australian Capital Territory
     4 Victoria
     5 Western Australia
     6 Queensland
     7 Northern Territory
     8 South Australia
     9 New Guinea
     10 New Zealand
     11 not known in Australasia
: 1
   6 TAXA REMAIN
DIFFS NO. NAME
   0 200 Digitaria
   0 223 Echinochloa
   0 484 Panicum
   0 495 Pennisetum
   0 625 Setaria
   0 736 Zea
: finish
```

Should further suggestions be required, and assuming that *Zea* is not selected, the possibilities offered by the first 5 genera could be explored at species level using Webster's automated descriptions of Paniceae (see Example 4).