**Information Management**

Computer databases are the most appropriate way to i) store large diverse data sets and ii) analyse them to answer a wide range of different questions. For example, if a site at 1,300 m elevation becomes available for forest restoration, the questions asked of a database might include...

* What tree species grow at similar sites at an elevation of 1,300 m?
* Of those species, which ones have fleshy fruits that attract seed-dispersing animals?
* Of those species, which ones are fruiting this month so that seed collection might commence?
* Of those species, which ones have previously germinated well in the nursery?

To generate lists of species, matching such specified criteria, it is necessary to construct a relational database to integrate all data produced by a FORRU, together with published data and indigenous local knowledge. Spreadsheets do not allow the sophisticated search, sort and integration facilities of dedicated database programs, and, the larger spreadsheets become, the more difficult they are to work with.

**Database structure**

Databases are like sophisticated card index systems. A “database file” is the equivalent of one box, containing many cards. A “record” is the equivalent of one card and a “field” represents one of the headings on the card and the information associated with it. It is not practical to store *all* information about a species in a single record, since, for some types of information, there will be a single entry (e.g. the name and characteristics of a tree species, which do not change) and for other types of information there may be many entries (e.g. germination trial results for each seed batch collected). Therefore, the database consists of several database files, each one storing a particular category of information.

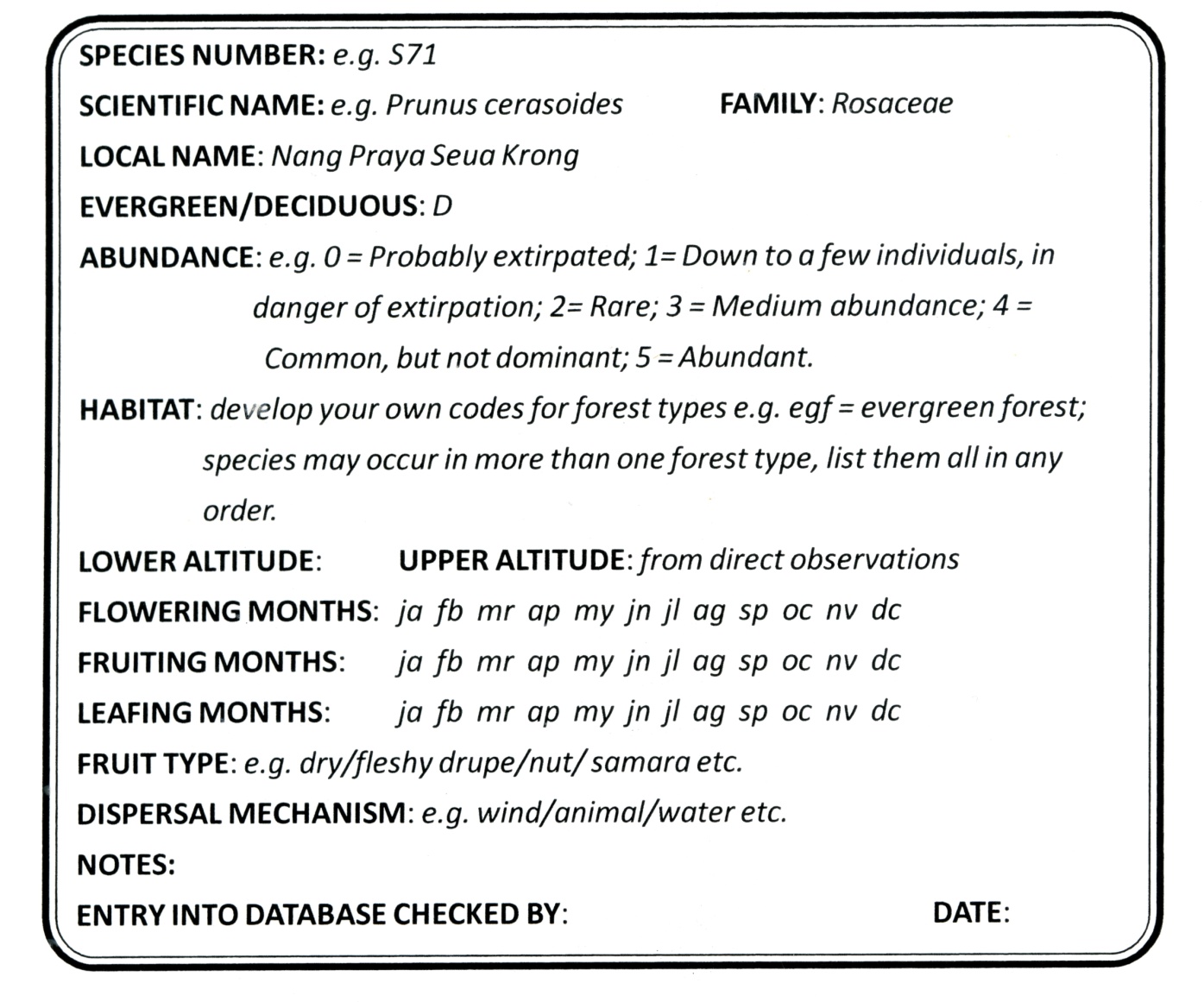
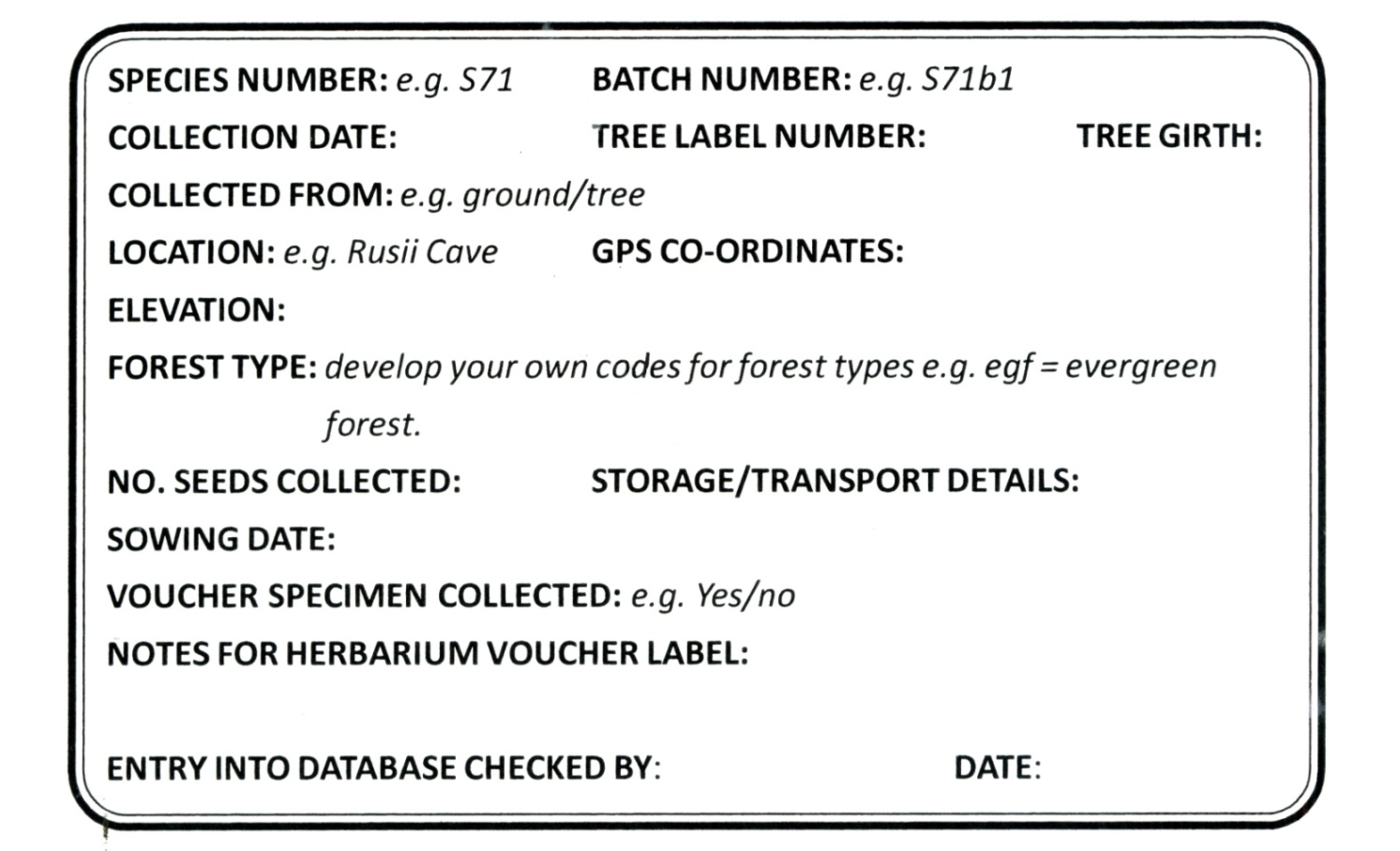
Furthermore, records referring to a particular species in each database file should be linkable with records referring to the same species in all other database files. Links are achieved by assigning link codes to each record, which enables records referring to the same species to be joined, regardless of which database file they are in. The most convenient link codes are the species number (S. no.) and seed batch number (b. no.), so it is of the utmost importance that these identification numbers appear on all datasheets and plant labels, both in the nursery and in the field. The database system uses these codes and group together records from all database files. Thus, the database can generate species reports, listing all information about each species. It is not a good idea to use species names (or abbreviations of them) as link codes, since taxonomists constantly change scientific plant names.

**Which database software?**

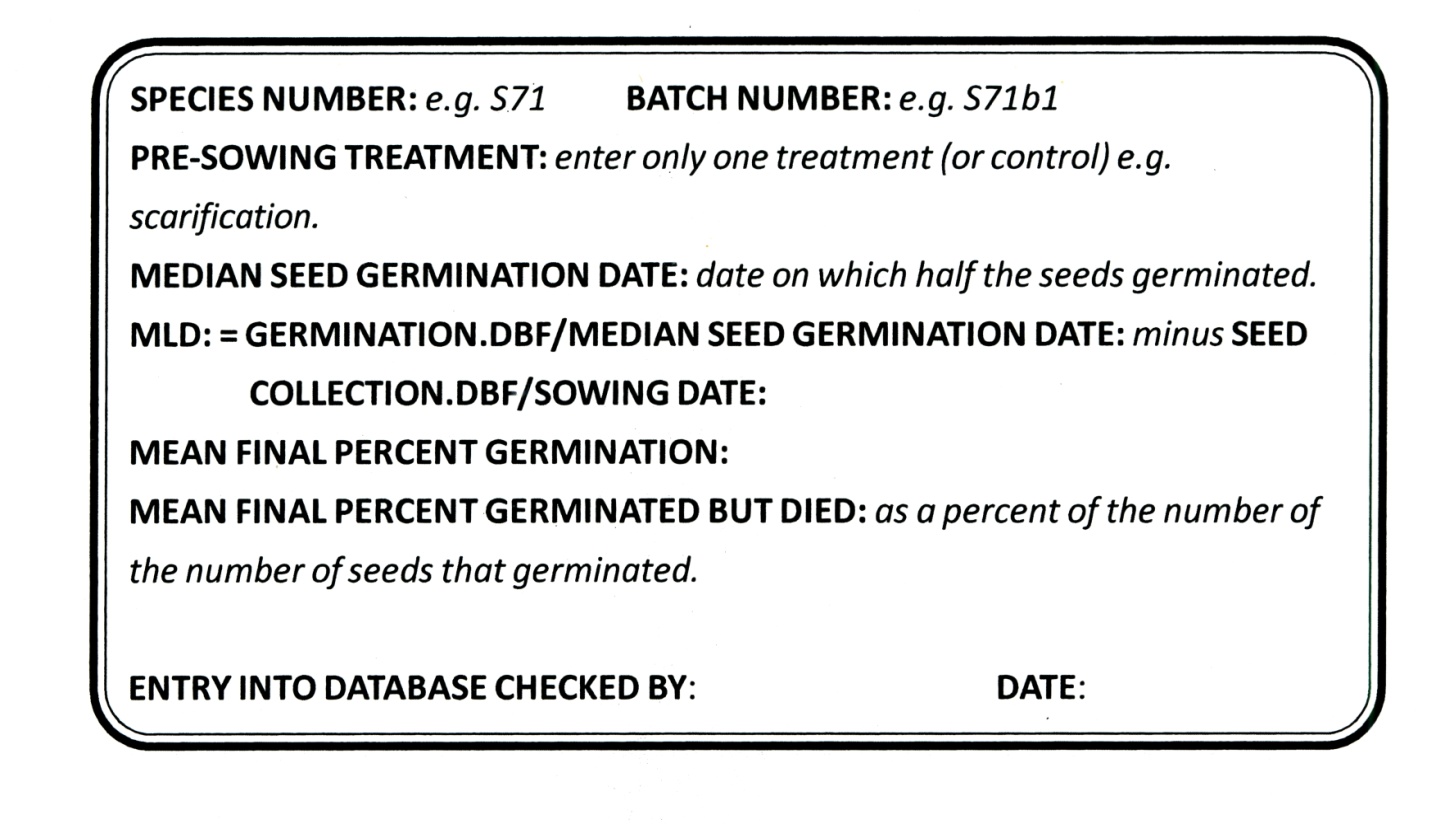
Database programmes vary in terms of their sophistication and ease of use. Unfortunately, the more sophisticated the program is, the less user-friendly it is. Microsoft Access is probably the most widely used database system, but it is expensive and there are several open source database programs available for free (e.g. Open Office).

**Suggested Files, Records and Fields**

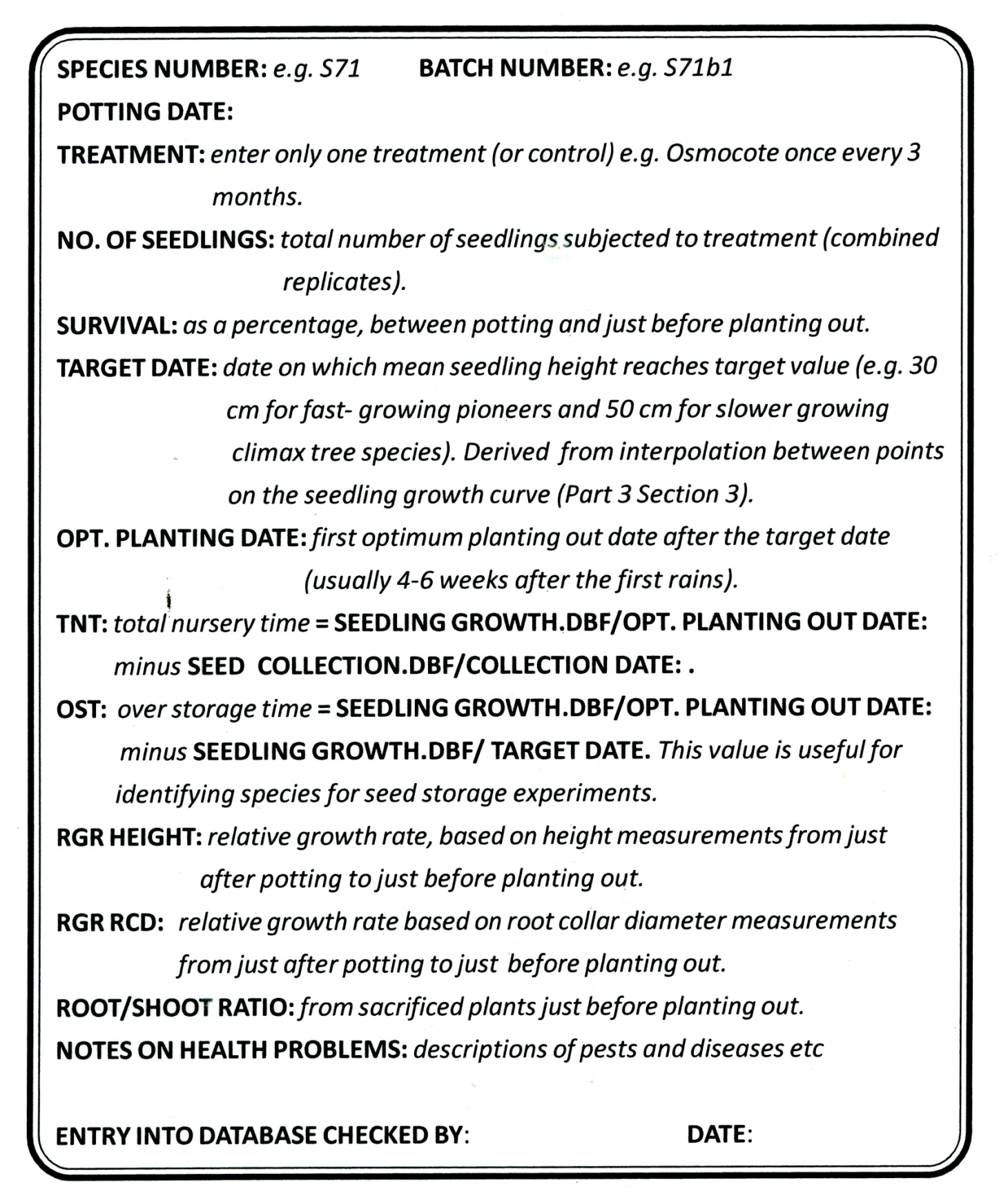
**DATABASE FILE - “SPECIES.DBF”** – basic information about each tree species studied, which can be linked to records in other database files through the “SPECIES NUMBER:” field. Most of this information can be retrieved from a flora. Modify the list of flowering and fruiting months, as data from the phenology survey become available.

**DATABASE FILE – “SEED COLLECTION.DBF” –** one record for each batch of seeds collected. Records for several seed batches for each species are linked to a single record in SPECIES.DBF” ****by the “SPECIES NUMBER:” field. Transcribe information from seed collection data sheets.

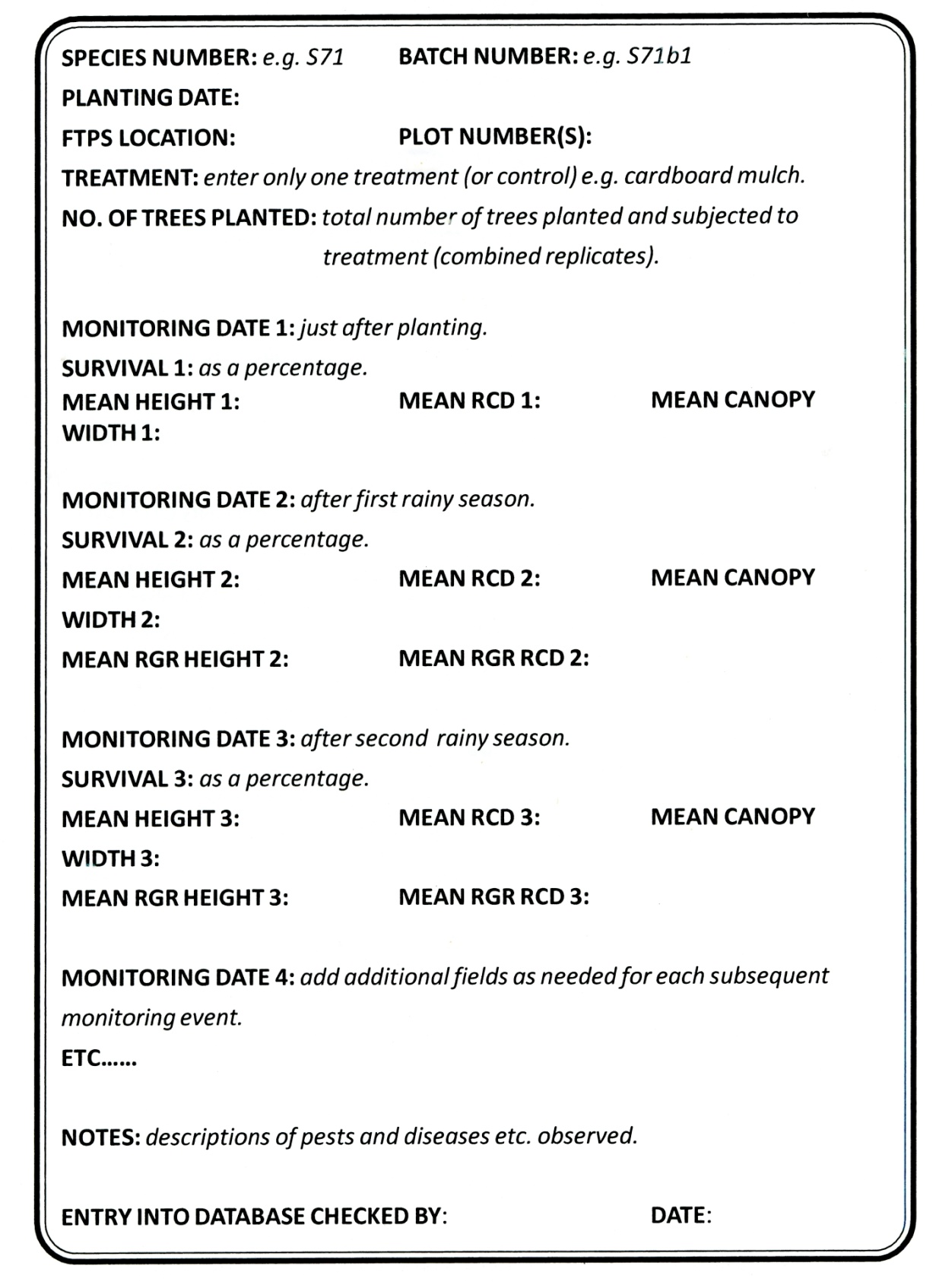
**DATABASE FILE – “GERMINATION.DBF”** one record for each treatment applied to each sub-batch of seeds. Multiple records for each species or each batch, respectively, are linked to a single record in “SPECIES.DBF” by the “SPECIES NUMBER:” and to a single record in “SEED COLLECTION.DBF” by the “BATCH NUMBER:” field. Extract data from germination data sheets.



**DATABASE FILE – “SEEDLING GROWTH.DBF”** - one record for each treatment applied to each batch. Multiple records for each species or each batch, respectively, are linked to a single record in “SPECIES.DBF” by the “SPECIES NUMBER:” field, and to a single record in “SEED COLLECTION.DBF” by the “BATCH NUMBER:” field. Extract data from seedling growth data sheets.



**DATABASE FILE – “FIELD PERFORMANCE.DBF”** - one record for each silvicultural treatment applied to each batch. Multiple records for each species or each batch can be linked to a single record in “SPECIES.DBF” by the “SPECIES NUMBER:” field, and to records in the other database files by the “BATCH NUMBER:” field. Extract data from the field data analysis spreadsheets (see Section 7.5). Insert mean values for combined replicates for a single silvicultural treatment.

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**Systems for selecting suitable tree species**

We suggest two simple semi-quantitative methods to facilitate the process of species selection: the “minimum standards” approach and a “suitability index”, based on a ranked scoring system. They may be used independently or in tandem, using minimum standards to create a short list of species, subsequently ranked by suitability index. They make best use of the data available, whilst retaining flexibility to meet the various objectives of different projects.

**Applying minimum acceptable standards of field performance**

The most important field performance criterion is survival rate after planting out. No matter how well a species performs in other respects (e.g. rapid growth, attractive to seed-dispersers etc.), if the survival rate after 2 years falls below 50% or so, then there is not much point in continuing to plant that species. Other additional minimum acceptable standards can be applied to growth rates, canopy width, suppression of weed cover etc., but all are subordinate to survival. The values of the minimum acceptable standards are largely subjective, although sensible values can usually be decided upon by scanning the data sets and looking for the divisions that set species apart – particularly values that contribute towards canopy closure within the desired timeframe.

Extract from the database field data collected after 18-24 months (at the end of the second rainy season in seasonal forests) into a spreadsheet with species names in the left-hand column, with data on the selected performance criteria arranged in columns to the right. Use mean values from planted control plots or mean values from whichever silvicultural treatment produced the best results.

Application of minimum standards results in three categories of species:

* Category 1 species – those that fall short of most or all minimum acceptable standards (i.e. rejected);
* Category 2 species - those that exceed some minimum standards but fall short of others (marginal), or only fall short by a small amount;
* Category 3 species - those that greatly exceed most or all minimum standards (i.e. excellent or acceptable).

Category 1 species are dropped from future plantings. Category 2 species may be either rejected or subjected to further experimentation, to improve their performance e.g. improve the quality of the planting stock or develop more intensive silvicultural treatments, whilst category 3 species are approved for further use.

Example:

The following standards are applied to field performance data, collected at the end of the second rainy season after planting:

* Survival: >50%
* Height: >1 m tall (since seedlings should be planted when 30-50 cm tall, this represents more than doubling of size)
* Crown width >90 m (i.e. more than half the distance required to close canopy, at a spacing of 1.8 m = 3,100 trees per hectare).

In the table below, data that fail to meet minimum standards are indicated in grey.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Species** | **% Survival** | **Mean Height (cm)** | **Mean Crown Width (cm)** | **Category** | **Action** |
| S001 | 89 | 450 | 420 | 3 | Accept |
| S009 | 20 | 62 | 65 | 1 | Reject |
| S015 | 45 | 198 | 255 | 2 | Research to increase survival |
| S043 | 38 | 102 | 20 | 1 | Reject |
| S067 | 78 | 234 | 287 | 3 | Accept |
| S072 | 90 | 506 | 405 | 3 | Accept |
| S079 | 65 | 78 | 63 | 2 | Research to increase growth |
| S105 | 48 | 82 | 77 | 2 | Research to increase growth and survival |

**What if too few species exceed minimum acceptable standards?**

There are several options:

* Improve overall planting stock quality – review the nursery data and check to see if there is anything that can be done to increase the size, health and vigour of the planting stock.
* Experiment with intensified silvicultural treatments (e.g. carry out weeding or apply fertilizer more frequently), particularly if you think site conditions may be limiting.
* Try different species – review all sources of tree species information (see Table 5.2) and start collecting seeds of species that have not already been tested.

**Developing a suitability index**

A semi-quantitative scoring system can be used to rank species according to a suitability index that combines a wide range of criteria. It can be applied either to refine the short list of acceptable (or marginal) species, which emerge from application of minimum standards or to all species, for which data are available. However, bear in mind that species with low field survival rates should always be screened out first, before calculating a suitability index.

In addition to easily quantifiable performance data, a suitability index can also take into account more subjective criteria, such as the attractiveness of each tree species to seed-dispersing animals. The simplest approach is to note whether species produce fleshy fruit or not. In older plots, this could be further refined by using the number of years to first flowering and fruiting, or the number of animal species that are attracted to a tree species.

Extract relevant data from the database and add additional information to a spreadsheet as required.

**Example**

TNT= “total nursery time” required to produce planting stock is used here to indicate ‘ease of propagation’. % germination or seedling growth rates in the nursery could also be used.

Before biodiversity data are available, ability to produce fleshy fruits can be used as an indicator of ‘attractiveness’ to seed dispersers

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Species** | **% Survival** | **Mean height (cm)** | **Crown width (cm)** | **Fleshy fruits** | **TNT (years)** |
| S001 | 89 | 450 | 420 | Yes | <1 |
| S015 | 45 | 198 | 255 | Yes | <1 |
| S067 | 78 | 234 | 287 | Yes | 1 to 2 |
| S072 | 90 | 506 | 405 | No | <1 |
| S079 | 65 | 78 | 63 | Yes | 1 to 2 |
| S105 | 48 | 82 | 77 | Yes | >2 |

In this example, species rejected as a result of applying minimum standards have been removed, whilst marginal values for some criteria remain indicated in grey.

Find the species with the highest mean height. Assign a value of 100% to that maximum mean height and convert the mean heights of all other species to percentages of the maximum value. In this example S072 has the highest mean height (506) so the heights of all other species are multiplied by 100/506. Carry out the same calculation for the other quantifiable criteria including nursery performance criteria as required (e.g. % germination, seedling survival, etc.).

Convert mean values into scores, all with potential values ranging from 0 to 100. Add extra weight to the criteria you feel are most important by multiplying them by a weighting factor (e.g. survival x2 in the example below). Sum the scores and, as before, convert them into a per cent of the maximum score (adjusted score). Then rank the species in order of declining overall score.

**Example**

TNT <1yr = 100;

1-2y = 75; >2y = 50

100 = fleshy fruits present; 0 = not present

Per cent of maximum score

Mean % Survival x2

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Species** | **Survival Score** | **Height Score** | **Crown Width Score** | **Fleshy Fruits Score** | **Ease of Propagation Score** | **Total Scores** | **Adjusted Score** |
| **Max Score** | **200** | **100** | **100** | **100** | **100** | **600** | **100** |
| S001 | 178 | 88.9 | 100.0 | 100 | 100 | 566.9 | 100.0 |
| S015 | 90 | 39.1 | 60.7 | 100 | 100 | 389.8 | 70.0 |
| S067 | 156 | 46.2 | 68.3 | 100 | 75 | 445.6 | 80.0 |
| S072 | 180 | 100.0 | 96.4 | 0 | 100 | 476.4 | 85.6 |
| S079 | 130 | 15.4 | 15.0 | 100 | 75 | 335.4 | 60.2 |
| S105 | 96 | 16.2 | 18.3 | 100 | 50 | 280.5 | 50.4 |

Based on the suitability scores above, S001, S015, S067 and S072, are the best species for planting, even though S015 would require some additional effort to increase survival. Lack of fleshy fruits in S072 is compensated by excellent scores for other performance criteria. Rejection of both of the other species which marginally failed to meet minimum standards (S079 and S105) is confirmed, since their adjusted suitability scores are only about half that of the most suitable species.

**Deciding on the species mix**

One of the disadvantages of applying standards or a scoring system too rigorously is that it may end up in the selection of only fast-growing pioneer species. This would result in a rather uniform forest canopy. Planting both pioneer and climax forest tree species together creates more structural diversity, even if some of the climax tree species fail to meet minimum standards or end up ranked low in a scoring system. So, when compiling the final mixture of species to be planted each year, use standards or scores as guidelines, rather than absolute rules. Be flexible and always keep in mind the need for diversity.

For example, a few slower growing tree species may be acceptable for planting if they score highly on other criteria (e.g. early fruiting) and where most of the other species being planted are fast-growing. Similarly, a few species with narrow crowns may be desirable, to add to the structural diversity of the forest canopy, provided they are planted alongside other species which score highly for canopy width. Ultimately the species mix is a subjective judgement, which is modified and improved each year as a result of adaptive management.

**What is adaptive management?**

Ideally final species selection, as well as other management decisions, would not be made until all the data had been collected and analysed. However, it may take many years before some of the field data are produced. Therefore, in the first few years of a FORRU, decisions are inevitably based on data that are produced early in the project e.g. phenological observations and seed collection and nursery data. Tree performance data from field trials follow later, whilst data on biodiversity recovery and establishment of recruit tree species become meaningful only after several years. Therefore, calculations of species suitability scores must be continually updated and modified, as new data become available. Maintaining and updating the FORRU database is critical to this process.

This is just one of several components of “adaptive management” – a concept central to the implementation of forest landscape restoration. Research results should feed into a social learning approach, based on a process of experiential decision-making and monitoring. The database effectively acts as an archive of the outcome of previous management trials and monitoring results, both good and bad, so that future decision making can gradually be improved.

The process only works if all stakeholders have access to the database and can understand the outputs. Outputs must therefore be presented in user friendly formats and it is also necessary to run an education and outreach program to ensure that all stakeholders can work with the database outputs and are thus well-equipped to participate meaningfully in management decisions.

Steve Elliott, 6/11/22