particular seedlot. The definition and terminology of provenance were thoroughly examined by Turnbull and Griffin (1984) and basically designates the place of origin of seeds or plants.

An obvious basis for choosing provenances is climatic matching, whereby natural stands with climate similar to that of the site selected for afforestation are identified. In some instances this may mean that provenances are selected from sites on the margins of the species distribution rather than from sites clearly within the main occurrence. One disadvantage of climatic matching is that little allowance is made for the possible existence of unexhibited adaptability (plasticity) within the species. The Lake Albacutya (Victoria) provenance of E. camaldulensis provides a striking example of plasticity: this provenance, from a Mediterranean climate, has performed reasonably well in tropical conditions (Ojo and Jackson 1973). The natural distribution of fire-sensitive species such as E. grandis or E. regnans may be restricted by the incidence of fire, but such species may tolerate a wider range of ecological conditions in plantations that are protected from fire. Whilst not a solution by itself, climatic matching can be a useful tool in helping match species and provenances to specified sites.

Selection of individual trees within a provenance

The number of trees to be sampled depends on the objectives of the collector. In most eucalypt provenance studies to date, the number of trees selected per provenance has been ten (Green 1971; Kirkpatrick 1975). Sampling in this manner is in accordance with the 1965 recommendations of Section 22 of International Union of Forestry Research Organisations, namely that a minimum of ten trees should be sampled and that the distance between selected trees should be greater than the distance of normal seed dispersal.

Within provenances, the sample from each tree is of greatest value if the trees are unrelated. The distance between closely related trees in eucalypt forests is unknown (Brown et al. 1976). The distance of seed dispersal is usually no greater than the height of the tree, and consequently the diameter of clusters of sibling trees in natural stands is unlikely to exceed twice this distance. To reduce the probability of sampling trees that are siblings, seed should be collected from trees at least a distance apart equal to twice the height of the trees.

It has recently become apparent that significant intra-provenance population differention may occur in at least some species (Burgess 1988), even in the absence of obvious environmental heterogeneity. This observation lends added support to the notion of extended sampling to obtain optimum base populations. Over the last decade there has been an expanding demand for individual tree seedlots because of certain advantages which these may have for use in breeding programs (Midgley 1987).

Timing of seed collection

For most eucalypts the time interval between flowering and seed maturation is usually long enough to give the collector, having checked the flower crop, time to prepare for seed collections. This interval is known for some species; e.g. about 6 months for E. fastigata (Fielding 1956), 8-10 months for E. regnans (Ashton 1975), 10-12 months for E. delegatensis (Grose 1957), 12 months for E. pilularis (Florence 1964), 10-16 months for E. diversicolor (White 1971). For E. brachyandra, however, the time between flowering and seed maturation may be as short as 1 month, while viable seed of E. gilbertensis have been collected from an inflorescence still bearing buds and flowers.

Eucalypt seed are usually mature when the fruit become brown and hard. In some instances seed are viable before they have fully 'matured' i.e. when the seedcoat is relatively soft and light in colour. Grose (1957) obtained viable seed of E. delegatensis 2.5-3 months after flowering, although the fruit do not normally mature completely until 10-12 months after the time of flowering.

Seed maturity can be quickly assessed in the field. The lines of dehiscence on the capsule become pronounced as the fruit matures and, once fully mature, the valves of the capsule usually open partially although the seed are not released. Non-viable immature seed are pale in colour, and the embryo is milky and rather soft when squashed. The maturity of seed can be tested by a transverse cut through the fruit, e.g. with secateurs; if the seed are mature they will be seen as white embryos within dark seedcoats, and brown chaff will also be present towards the top of the capsule.

The time between fruit maturation and seed shed varies considerably from species to species; Pederick (1960) found that a mature seed crop will remain on E. obliqua trees for up to 2 years, and there are many species with the same characteristic. For this reason the timing of collections for some species is not critical. Correct timing, however, is essential for species such as E. papuana, which have thin-walled fruit that dry and begin to shed seed within a few days of maturation. Seed shed is certainly hastened by hot, dry weather. A guide to the time period that mature seed crops remain on the trees of different species is given in Boland et al. (1980).

If large quantities of seed are required the collector should be aware that some species yield heavy seed crops only after several years of sparse production. Species such as E. camaldulensis, E. grandis and E. saligna usually bear heavy seed crops every 2-3 years. In E. regnans this period is every 2-4 years (Ashton 1956; Cunningham 1960). Consequently, major collecting efforts are best made during years of peak seed production so that seed can be stored for use in years when the seed crops are small.

Factors affecting seed yield

Seed yield is often expressed in terms of the total weight of seed and chaff produced on a single eucalypt tree. Because the size of seed varies enormously with species, and because the ratio of seed to chaff may vary with individual trees, the weight of seed and chaff produced is not a good measure of the yield of pure seed. A better measure of seed yield, albeit not quickly available, would be the number of potential seedlings that a tree could produce. Some of the more important factors influencing seed yield are tree age, crown size, seasonal weather conditions and various seed-destroying pests.

The age at which eucalypts first produce seed varies from species to species. Pederick (1976) noted that cultivated trees of E. leucoxylon will flower as early as age 2 years, while those of E. woodwardii have been observed to flower before they are 1 year old (D.A. Kleinig, pers. comm.). Barrett et al. (1975) observed in a 6-year-old plantation that about 64% of E. grandis trees formed floral buds or flowers, compared with 36% of E. saligna, 3% of E. botryoides and less than 1% of E. deanei trees. No flowering was observed for E. dunnii trees.

Relative crown size or class is an important factor in determining the yield of seed. About 80% of the total seed weight in a stand has been estimated to occur on the dominant trees in E. regnans and E. delegatensis (Jacobs 1955; Cunningham

1960). Dominant trees of E. grandis produce more seed with a higher viability than codominant trees with fairly poor crowns; thus Floyd (1961) recommended that seed collection should be confined to the dominant and better codominant trees. Burgess (1970) reported that dominant trees of E. grandis carry two or three times as much seed as a large-crowned codominant or about eight times as much seed as a small-crowned codominant.

There is considerable variation in seed yield from tree to tree, even among trees growing close together. Pederick (1960) found that the number of viable seed per unit weight in E. obliqua varies from year to year on individual trees but found no evidence that some trees regularly gave a higher seed count per unit weight of seed and chaff than others. The number of seed produced appeared to be influenced by external factors such as the efficiency of pollination and the relative abundance of insects causing damage to the seed. Eldridge (1963) reported an attempt to increase the number of viable seed per unit weight in E. regnans by introducing bees at the time of flowering, but he obtained no evidence that seed yields could be increased in this way.

Adverse weather conditions can prevent the continued development of seed at the bud, flower or fruit stage and so affect the final seed yield. Very hot, dry weather can cause buds and flowers to fall prematurely. Strong winds, bushfires and frosts can be damaging, particularly if the floral organs are small and fragile. Fires of low intensity can bring about almost total seed release in some species (Cremer 1965).

Collection methods

The method employed depends on the amount of seed required and the height of the tree. Only short trees less than a few metres tall are simply sampled. Taller trees require special methods.

In Australia seed are usually collected in bulk from trees felled for timber harvesting or occasionally from trees felled specifically for this purpose. Smaller quantities, especially for research, are usually collected from standing trees.

Collection from standing trees

Climbing. This is difficult and very costly, particularly where labour costs are high and the trees are large, and the method is rarely used in Australia. The scaling of eucalypt boles is difficult since trees typically shed their lower limbs. Even when the climber is within the crown the fruit are usually out of reach because they are borne at the ends of the branches and the only way to obtain them is to cut the branches off near the base.

The collection of eucalypt seed from standing trees is common in some countries, e.g. Brazil, where selected trees are scaled with the aid of climbing spikes and a safety belt. About one-third of the tree crown may be removed every 3 years to obtain seed. Although climbing spikes can damage the bark, climbing may be the only practical method for collecting large quantities of seed from standing trees. A method useful when collecting in restricted areas, such as national parks, is to establish a single rope in the crown of the tree and to use advanced climbing techniques and equipment devised for caving to get the collector into the crown.

Throwing-rope. A rope with a weighted end can be thrown over small branches, which are then broken off if the free and weighted ends are held together and pulled. Branches up to 12 m above the ground can be reached by this method. For higher branches more sophisticated methods can be used, e.g. a nylon fishing line with a weighted end can be projected over a branch by means of a catapult. Once the line is over the branch a heavier rope of greater breaking strain can be attached to the line and hauled across the limb. This method was described in detail by Hyland (1972).

Throwing-rope in conjunction with a flexible saw. The flexible saw, which in Australia is also known as a 'commando' saw, consists of pairs of teeth individually jointed so that the saw can be folded into a circle of about 10 cm in diameter. Fully extended it is about 1 m long with brass eyelets at each end for attaching either ropes or handles.

To operate the 'commando' saw a light rope is first thrown over the desired branch and the saw, with heavier ropes tied at each end, is drawn up. Some skill is necessary to raise the saw into a cutting position. Once in position a person at each end of the rope can work the saw across the branch and quickly bring down quite large limbs. The saw can be most easily manoeuvred into position on more or less horizontal limbs, e.g. those of E. camaldulensis, but on acutely ascending limbs characteristic of species such as E. tereticornis the task is more difficult.

Rifle with telescopic sight. Branches may be removed from very tall trees by means of a rifle. The selection of branches and the position along the branch at which the shots are to be placed is critical. It is important to select branches that will fall unobstructed to the ground and to position the shots at a point along the branch so as to take advantage of branch weight and leverage as the shots begin to take effect.

The use of a rifle for this purpose is expensive and is mostly used when only small samples of seed are required. However, the method is economical if the seed crop is heavy and most commercial seed collectors in Australia effectively use the technique. Good results have been achieved with .222, .243 or .308 calibre rifles. At the Division of Forestry and Forest Products, we prefer the .308 calibre rifle fitted with a 4X magnification telescope and using soft-nosed bullets (Kleinig and Boland 1977). With this rifle branches up to 15 cm in diameter may be removed from very tall trees.

Pole pruners. Pole pruners are sometimes used for cutting down small branches. Extending poles can be used to reach heights of up to 10 m but become increasingly difficult to use as the height increases. They can be used effectively on small to intermediate sized trees when it is necessary to restrict damage to the tree to a minimum, e.g. when seed are being collected in a national park.

Collection from felled trees

Trees felled in commercial logging operations. The collection of seed from trees that have been felled in a commercial logging operation is usually the least expensive method of obtaining large quantities of seed. Selective logging operations, where only the better formed and highest quality trees are felled, are particularly suitable for large-scale collecting. However, the fruit of some species may break off and scatter when the tree strikes the ground. This is a common problem with E. cloeziana, E. citriodora and E. torelliana.

Removal of the fruit from the branches.

Once the branches are on the ground the fruit may be stripped off by hand or with a rake. In some species it is better to use secateurs or a machete to cut twigs bearing fruit although this involves considerable time and labour.

Eucalypt fruit awaiting extraction must be well ventilated to prevent the growth of fungi. Small samples of fruit or branch clippings may be stored loosely packed in cloth bags. Particular care must be taken when the fruit is stored in hot humid conditions to prevent it from remaining moist and then rotting.

Extraction

The methods employed for extracting eucalypt seed are influenced by prevailing weather conditions and the amount of seed required.

Mature eucalypt fruits open readily when dried. Care must be taken not to expose seed to high temperatures while they are still moist as they can be readily damaged by such treatment. Hodgson (1956) found that E. obliqua seed could withstand temperatures of 55°C for up to 1 h with little effect on their viability, provided that the initial moisture content was low. At high moisture content the viability was drastically reduced within a few minutes. Boden (1957) observed that E. pauciflora seed could withstand a temperature of 96°C for 1 h when dry but could not tolerate temperatures above 75°C when moistened.

Because eucalypts grow in a wide range of climates, both natural and artificial drying methods are in common use and the method chosen depends on local conditions. In hot, dry, climates natural, open-air drying is adequate and does not present any problems in seed extraction, but in cool, humid climates the release of seed from the fruit is very slow unless artificial heating is used.

Natural drying. Small collections of fruit or fruit-bearing branchlets can be spread out in a thin layer on canvas or calico sheeting in a dry and well-ventilated position either in the sun or in the shade. A box with a wire mesh a few centimetres from the bottom and a sheet of clear plastic or glass over the top forms an effective seed extractor (Boden 1972). The fruit placed on the mesh should be shaken daily and the seed removed so that they are not exposed to high temperatures for longer than necessary.

Large collections of fruit are often spread on tarpaulins placed in special concrete enclosures or raised up above the ground in frames or on wires. Collection of seed from fruit-bearing branches spread on the ground is expensive because of the frequent turning required to permit the lower layers to dry out, although it requires little equipment. A more satisfactory method is to spread the fruit over a suspended frame covered with wire netting to allow air to circulate around the fruit. A canvas sheet underneath the frame catches the seed as they are shed. Such structures may be large or small, permanent or temporary. Small temporary frames are suitable for use by the mobile seed collector; the large structures are used in permanent seed-extraction facilities.

Fruit-bearing branches are sometimes hung from a horizontal strand of wire, a method than ensures very good circulation of air and avoids the risk of the material becoming compacted and overheated. The seed are collected on a sheet placed under the branches. This method can be used in the forest or in a well-ventilated shed. The latter arrangement is preferred when there is a high risk of rain during extraction.

In a system that has been developed in Brazil, the fruit are placed on shelves in trolleys with a capacity of about 50 kg. During the day the trucks are left in the sun and at night or during rain they can be wheeled under cover. The fruit usually open in about three days (Cavalcanti and Gurgel 1973).

The time required for natural drying depends on a number of factors including species, fruit maturity and, most importantly, the conditions used to dry the seed. Mature fruit of some species can release their seed within a few hours under optimum drying conditions, e.g. E. microtheca, but most species usually take 2-4 days. Some eucalypt species retain unopened fruit on the tree for several years, after which time they become very woody and are often difficult to open.

Although fruit open rapidly when they are dried in full sunlight there is a risk that any initial dormancy in the seed will be strengthened if the temperature becomes too high. Consequently the fruit should not be placed directly on metal that is exposed to the sun. Ants may pilfer seed during the drying process and preventative measures are sometimes necessary.

Artificial drying. Seed drying kilns are used in Australia when there is a requirment for very large quantities of seed in cases such as the aerial broadcasting of seed to supplement natural regeneration. Basically, most kilns hold the fruit-bearing branches in a rotating cylinder through which warm air is passed.

The Australian Tree Seed Centre uses a drying room for seed extraction when weather conditions do not permit natural drying. Seed-bearing branches are loaded onto moveable trays within the heated (35°C - 40°C) and dehumidified room. Large electric ovens containing sliding shelves are used in Brazil.

Extraction

After drying, the fruit must be vigorously shaken, particularly if they are not fully mature, otherwise abscission of the seed from the placentae may be only partially effected. If slightly immature fruit are not shaken it is possible that only the chaff will be released. Because fertile seed are usually attached to the placentae near the bottom of the fruit loculi, the immature fruit may on superficial examination appear to be empty after the chaff is shed. Seed are more easily extracted from fruit of species with half-superior ovaries, e.g. E. camaldulensis, than from fruits of species with fully inferior ovaries, e.g. in E. delegatensis; in the former case the valves spread more easily since they are not encumbered by the rim of the fruit.

Cleaning

Extracted 'seed' usually consist of a mixture of fertile seed and chaff, plus larger particles such as fruit, twigs and leaf debris. The fertile seed and the chaff can usually be separated from the other matter by sieving.

The proportion by weight of viable seed in a seedlot may vary greatly from species to species: 16% in the case of E. diversicolor (Anon. 1966) and 20% in the case of cultivated E. grandis (Hodgson 1975). Yacubson (1961) in Argentina found that the fraction of fertile seed in _E. camaldulensis_ was 40% and about 10% in _E. viminalis_. Approximations determined by the CSIRO Division of Forestry and Forest Products for other species are 25% for _E. setosa_, 20% for _E. globulus_ subsp. _bicostata_ and 86% for _E. torelliana_ (an unusually high figure for a eucalypt species). Grose and Zimmer (1958b) stated that for many eucalypts, viable seed comprises 3-20% of the natural seedlot.

Although commercial seedlots are a mixture of seed and chaff, some users strongly prefer pure seed. The latter is particularly useful for direct sowing into containers because the number of seed per container can be better regulated.

The difficulty of separating the viable seed from the chaff again varies with species. Most problems occur in species in which seed and chaff are similar in size, specific gravity and colour. Species in this category are _E. cloeziana_ and most _Monocalyptus_ spp. In the case of _E. cloeziana_ the difficulty in separation is illustrated by Guldager (1973), who reported no success with water grading and sieving and only partial success when a vibrating gravity table was used.

Mechanical methods of removing the chaff and other impurities from the viable seed depend on sieving, winnowing and the use of specific gravity techniques.

Sieving

With sieves of suitable mesh size it is possible to separate the viable seed rapidly from the chaff in many species. Complete separation can be achieved with species such as _E. citriodora_ and _E. maculata_, which have viable seed much larger than the chaff. In other species, such as _E. saligna_ and _E. grandis_, viable seed are always contaminated with a small fraction of chaff of similar size. Loss of the very smallest seed in the sieving process may not be serious because they usually germinate slowly and are low in vigour (Grose and Zimmer 1958b; Candido 1970; Akhtar 1973), but it could introduce a genetic bias to the seedlot.

Blowers

Air blowers are useful for eucalypt seed separation. The machine is adjusted so that the light chaff and debris are picked up by an ascending column of air and removed from the heavier fertile seed by means of baffles attached to the inside of a clear plastic tube near the top of the air column. The method is suitable only for small seedlots unless the apparatus is fitted with a mechanism that allows a continuous feed.

Specific gravity separators

A specific gravity separator has been used to separate seed from chaff in E. grandis, E. tereticornis and E. paniculata (Guldager 1973). E. grandis seed of 95% purity can be extracted by this means compared with the normal level of purity of 10% in this species. A seed mixture is placed at the top of an inclined tray which, when vibrated by means of an electric motor, causes the seed to roll in one direction while the lighter chaff and debris move in another.

Storage

Seeds are considered to be at their physiological peak at maturity, and from that point on vigour declines, due to the ageing process, until death occurs. The environmental conditions of storage influence the ageing process.

At the Australian Tree Seed Centre we have found that mature seed of most eucalypts can be kept viable for 5-20 years if stored at a low moisture content (8-10%) in sealed containers at 3-5°C. Many species can be stored for up to 10 years at room temperature with some loss of viability; complete loss of seed viability occurs in some species by 15 years, and in most by 20 years. However, loss of seed viability may not adequately reflect the loss in seedling vigour with time. With many species, when viability has been reduced to about one half of the original, seedling vigour has declined to a point where most seedlots should be discarded. For very long-term storage, sub-freezing temperatures (e.g. -18°C) are desirable. Of the more important commercial species, E. obliqua and E. diversicolor seed appear to lose their viability sooner than average.

Doran et al. (1987) reported that at room temperature (ca. 24°C), germination and vigour of high quality E. camaldulensis seedlots were maintained for more than 8 years. Despite this encouraging result, other seedlots of this species are known to have deteriorated significantly in this regime over a similar time span. They recommended air-tight refrigerated storage, and preferably a deep freezer at ca. -15°C for long term storage of E. camaldulensis seed, rather than risk the possibility of significant decline at room temperature.

The seed of E. deglupta can deteriorate rapidly if stored at room temperature and must be kept in airtight containers sub-freezing temperatures. Storage of E. microtheca seed in a freezer can be safely recommended for maintenance of viability to 8 years and possibly longer, while the cool-room environment is suitable for medium term (to 4 years) storage. Storage at higher temperatures (ca. 24°C) for more than 2 years is ill advised because of rapid decline in the germination and vigour of some seedlots.

It should be stressed that temperatures cannot be considered in isolation, but must be examined in conjunction with seed moisture content. It has been demonstrated by Barton (1961) that at a given moisture content, the higher the storage temperature, the faster the deterioration of seed viability, whereas there is a greater tolerance of high moisture content at lower storage temperatures.

Although it is widely accepted that the moisture content of seed is a critical factor in determining longevity in storage, the relationship has received little investigation in Eucalyptus. Limited tests in Australia have indicated that an adequate storage life for most species can be achieved if the moisture content is in the range 4-8%.

Suiter and Lisbao (1973) observed rapid increases in seed moisture when the humidity of the air surrounding the seed was higher than 60%. If seed are extracted in humid conditions the moisture content of the seed may have to be reduced by further drying if extended storage is required. When seed are not stored in moisture-proof containers it is advisable to maintain a relative humidity in the storage room of between 20 and 40%.

High temperature and humidity in storage also increase the risk of seed damage due to fungi and insects. The spores of parasitic fungi, such as Fusarium sp., can grow on the seed surface and kill seeds when storage conditions are inappropriate. Insect development is inhibited when the seed moisture content is below 8 per cent and the temperature decreases to 5-10°C. At sub-freezing temperatures insects do not survive.

Fumigation

Eucalypt seed should be fumigated before storage to kill insect pests. The Australian Tree Seed Centre routinely fumigates all seedlots with carbon dioxide. Seedlots are sealed in laminated plastic bags in a carbon dioxide atmosphere for 2 weeks. This has the advantages of maintaining the seed in a dry atmosphere, unaffected by changes in ambient humidity; it effectively fumigates against insects and is non-toxic to those handling the seed. There are no indications from preliminary data that viability is reduced. Shrestha et al. (1985) found in controlled atmosphere storage trials for Pinus radiata that carbon dioxide maintained seed viability and enhanced seedling vigour. These results are promising and have major implications for future storage regimes.

Other fumigants sometimes used include carbon disulphide and paradichlor-benzene, but concerns for user safety limit use on a large scale.

Dormancy and seed treatment prior to germination

Dormancy is defined as a physiological state in which a seed predisposed to germinate does not, even in the presence of favourable environmental conditions (Bonner 1984). Seed dormancy aids the survival of wild plant populations by preventing germination at unfavourable times and by spreading the germination over many weeks, thereby increasing the opportunities for successful seedling establishment. In contrast, this mechanism presents a problem to a nursery worker attempting to produce large uniform seedling crops in a short time. The mechanisms that restrict germination vary widely, but in most cases dormant seeds can be induced to germinate within a reasonable time if certain conditions are satisfied.

The incidence of seed dormancy within the genus Eucalyptus is largely confined to species occupying the sub-alpine and cold temperate zones of south-eastern Australia. The dormancy may be present when the seed is collected (primary dormancy) or subsequently induced or strengthened (secondary dormancy) by exposure of seeds with a high moisture content to high temperatures (Grose 1963; Beardsell & Mullett 1984). At high altitudes in Victoria, seed of E. delegatensis dispersed in summer has primary dormancy strengthened by high temperatures, and so germination is delayed until spring (Grose 1961, 1963). The degree of dormancy can vary between populations of a species in different localities. Beardsell &

Mullett (1984) found that fresh seed of two alpine populations of E. pauciflora as partially dormant and became completely dormant after storage for one year at room temperature whereas seed from two lowland populations as not dormant. Provenances of E. glaucescens have also shown considerable variation in dormancy (Doran & Gunn 1979).

The mechanisms, origin and occurrence of seed dormancy in eucalypts are poorly understood. For E. delegatensis and E. pauciflora there is some evidence that the seed coat mechanically restrains the embryo (Bachelard 1967a) and also critically slows the exchange of oxygen (Grose 1963). However, it seems probable that in some species at least it is an endogenous dormancy due primarily to the condition of the embryo, as dormancy can be broken only by factors such as chilling treatments and growth stimulators which bring about physiological change. Bachelard (1967b) found that the germination of dormant seed of E. delegatensis, E. fastigata and E. regnans could be improved by treatment with gibberellic acid. But the most effective treatment for all eucalypts has been to hold fully-imbibed seeds at a temperature of 3-5°C from three to six weeks or longer (Boland et al. 1980).

A procedure for cold moist stratification is:

- Divide the seed into lots corresponding to a unit of sowing area equivalent to a seed tray or seed bed, so that the seed can later be sown at the correct density.

- Place the lots in containers (thick polythene bags are suitable) and add several times the seed volume of cold water. Place in a refrigerator at c. 3-5°C for forty-eight hours, making sure the seed remains wet.

- Drain the seeds and leave them in the polythene bag, lightly tied, in refrigeration at 3-5°C.

- Each week for the duration of the treatment, open the containers, mix the seeds and remoisten if the seed shows any sign of drying out.

- At the end of the treatment, spread the seed thinly on trays and allow to surface-dry without artifical heat in a cool, shaded and well-ventilated area. The drying is not essential, but makes the seed easier to sow.

Three weeks of stratification are essential to break the dormancy of seed of E. perriniana and will also ensure more rapid and even germination for E. amygdalina, E. dives, E. nitens, E. pauciflora subsp. pauciflora, E. regnans and E. stellulata. Four weeks of stratification are essential for the germination of seed of E. glaucescens and E. pauciflora subsp. niphophila; 6 weeks are required for E. kybeanensis, E. mitchelliana and E. pauciflora subsp. debeuzevillei, while E. delegatensis requires 6-10 weeks, depending on seed source. On subsequent transfer to warmer temperatures germination should commence within 3-5 days.

Procurement of seed of Australian origin

There are many reasons for returning to the native eucalypt forests in Australia for seed. It is often a very quick way to obtain high quality seed in required quantities. It may be necessary to broaden the current genetic base or it could be necessary to counter in-breeding in plantation-produced seed. For tree improvement programs it is vital to have a broad genetic foundation.

There are many suppliers of Australian tree seed, most of whom are listed in a brochure produced by the Australian Tree Seed Centre, Australian Suppliers of Tree Seed. Most commercial seed collectors can specify the origin of the seed they supply. There is however no tree seed certification scheme operating in Australia, and it is recommended that the purchaser ascertain details of seed origin before entering into any purchase agreement. The minimum details which might be expected are the precise locality of collection including latitude, longitude and altitude of the collecting site, year of harvesting and number of trees sampled. Purchasers should not assume that the seed of eucalypts or other Australian genera will necessarily be supplied from trees growing in Australia. Seed from exotic plantations is now common in the seed trade. The listing of a supplier in the leaflet does not imply endorsement by CSIRO.

Increasingly, the large users of eucalypt seed are engaging the services of Australian suppliers to make specific collections. This has proved to be a very cost-effective method of obtaining seed of required species and provenances. It is common practice for foresters who use the seed to visit Australia to accompany the seed collecting teams. This provides a valuable opportunity for them to become familiar with the ecology and population structure of Australian species in their native occurrence.

The Centre has, in recent years, undertaken many collaborative seed collections with organisations as diverse as ALCOA of Australia (a large mining company), CELBI of Portugal, W.A. Chip and Pulp and APPM (large Australian forestry companies), Wiggins Teape of the United Kingdom, the US Department of Agriculture and many multilateral and bilateral donor agencies (e.g. FAO, U.S. Agency for International Development, IDRC (Canada), GTZ (Germany), CTFT (France)). The Centre has received an increasing number of requests for seed from researchers in Chile over the past few years. Given the number of companies and organisations involved with species selection and tree improvement of eucalypts, it might be appropriate if the forestry organisations in Chile were to consider collaborative collections of seed of high-priority species. CSIRO undertook such an exercise with Brasil's EMBRAPA in 1983-84. Brasilian forestry companies pooled their resources and financed EMBRAPA to undertake seed collections in Australia to meet their joint seed requirements for tree improvement and research. EMBRAPA and CSIRO entered into a formal agreement and a Brasilian forester came to Australia and, worked for one year with a contracted professional counterpart team based at the Australian Tree Seed Centre. The program was regarded by both CSIRO and EMBRAPA as a complete success.

Record keeping

Detailed records are a crucial element of seed supply and procurement. The computer-based record system used at the Australian Tree Seed Centre, was described by Wolf and Turnbull (1982). This system has been further developed since that account was published. A version of the system is now available for IBM-type personal computers (Appendix A).

The Australian Tree Seed Centre

The Australian Tree Seed Centre (ATSC), part of CSIRO's Division of Forestry and Forest Products, has acted for 25 years as a national tree seed bank. It supplies seeds of Australia's unique woody flora to researchers in Australia and over 100 other countries. It is a national focus for both the import and export of tree seed and is a recognised source of knowledge of the practical use of the Australian flora. The Centre provides technical advice on species selection and silviculture and conducts research on seed collection, germination, extraction and storage methods. The Centre also collaborates in studies of genetic variation in Australian tree species. Staff of the Centre have, over the past 10 years, written over 175 papers, written or contributed to the production of 9 books, produced a series of eucalypt and acacia leaflets and provided on-site consultant services to over 20 countries.

Conclusions

Knowledge and facilities for the acquisition of eucalypt seed of high quality, in both a physiological and genetic sense, are well developed now. In view of the crucial role of seed in both research and plantation practice effort and money spent to procure high-quality material is potentially a very rewarding investment. It costs just as much to establish a plantation with seed of poor quality as it does with seed of the highest genetic potential, but the difference in long-term production, quality and profitability may be great.

Acknowledgements

Much of this paper has been based upon the book produced by the Australian Tree Seed Centre, 'Eucalyptus Seed' by D.J. Boland et al. (1980). It is a pleasure to acknowledge the help of colleagues Mr Alan Brown, Mr John Doran and Mr Lex Thomson, who reviewed the manuscript. The opportunity offered by the Chilean Instituto Forestal to visit Chile is appreciated.

References

Akhtar, S. (1973). Germination responses of some common eucalypts. Pakistan J. For. 23, 48-63.

Anon. (1966). Forestry in Western Australia. 2nd ed. Revised. Bull. For. Dept. W. Aust No. 63.

Anon. (1972). Handbook on eucalypt growing. Wattle Research Institute; Natal.

Ashton, D.H. (1956). Autecology of Eucalyptus regnans F. Muell. Ph.D. thesis, Univ. of Melbourne.

Ashton, D.J. (1975). Studies of flowering behaviour in Eucalyptus regnans F. Muell. Aust. J. Bot. 23, 399-411.

Bachelard, E.P. (1967a). Effects of gibberillic acid, kinetin, and light on the germination of dormant seeds of some eucalypt species. Aust. J. Bot. 15, 393-401.

Bachelard, E.P. (1976b). Role of the seed coat in dormancy of Eucalyptus pauciflora and E. delegatensis seeds. Aust. J. Biol. Sci. 20, 1237-40.

Barrett, R.L., Carter, D.T., and Seward, B.R.T. (1975). Eucalyptus grandis in Rhodesia. Rhodesia Bulletin of Forestry Research, Rhodesia For. Comm., No. 6.

Barton, L.V. (1961). 'Seed Preservation and Longevity.' (Leonard Hill: London.)

Beardsell, D., & Mullett, J. (1984). Seed germination of Eucalyptus pauciflora Sieb. ex Spring from low and high altitude populations in Victoria. Aust. J. Bot. 32, 475-80.

Boden, R.W. (1957). Some aspects of seed dormancy in Eucalyptus. Aust. For. 21, 81-5.

Boden, R.W. (1972). Plant propagation. In The Use of Trees and Shrubs in the Dry Country of Australia. (N. Hall et al.) pp. 420-34. (Aust. Govt. Publ. Serv. Canberra).

Boland, D.J., Brooker, M.I.H., Turnbull, J.W. and Kleinig, D.A. (1980). 'Eucalyptus Seed.' (CSIRO: Melbourne).

Bonner, F.T. (1984). Glossary of seed germination terms for tree seed workers. U.S. Dept. Agric. Forest Service Southern For. Exp. Sta. Gen. Tech. Report 50-9.

Brown, A.G., Eldridge, K.G., Green, J.W., and Matheson, A.C. (1976). Genetic variation of Eucalyptus obliqua in field trials. New Phytol. 77, 193-203.

Brown, A.H.D., Matheson, A.C. and Eldridge, K.G. (1975). Estimation of the mating system of Eucalyptus obliqua L'Herit. using allozyme polymorphisms. Aust. J. Bot. 23: 931-949.

Burgess, I.P. (1970). Eucalypt seed: demand and supply in northern N.S.W. Proc. 2nd Meet. Res. Wkg. Group No. 1. Tree Improvement and Introduction. Aust. For. Counc., Beerwah, Australia.

Burgess, I.P. (1988). Provenance trials of Eucalyptus grandis and E. saligna. Silvae Genetica (In press).

Candido, J.F. (1970). The effect of seed size and environment on the germination of Eucalyptus citriodora seed. (In Portuguese.) Revista Ceres Vicosa 17(91), 77-85.

Carr, S.G.M., and Carr, D.J. (1962). Convergence and progression in Eucalyptus and Symphyomyrtus. Nature 196, 969-72.

Carr, D.J., and Carr, S.G.M. (1987). Eucalyptus 11. The rubber cuticle, and other studies of the Corymbosae. (Phytoglyph Press, Canberra).

Cavalcanti, G.R.A., and Gurgel, J.T.A. (1973). Eucalyptus seed production in Brazil. Proc. Internat. Symp. Seed Processing, Gergen, Norway. Vol. II, paper No. 8.

Cremer, K.W. (1965). Effects of fire on seedshed from Eucalypts regnans. Aust. For. 29, 252-62.

Cremer, K.W., Cromer, R.N., and Florence, R.G. (1978). Stand establishment. In 'Eucalypts for Wood Production'. (Ed. W.E. Hillis and A.G. Brown). pp. 81-135 (CSIRO : Melbourne).

Cunningham, T.M. (1060). The natural regeneration of Eucalyptus regnans. Bull. School For. Univ. Melbourne No. 1.

Doran, J.C. and Gunn, B.V. (1979). The effect of stratification on the germination of six different provenances of Eucalyptus glaucescens seed. Aust. Seed Sci. Newsletter 5, 19-25.

Doran, J.C., Turnbull, J.W., and Kariuki, E.M. (1987). Effects of storage conditions on germination of five tropical tree species. In Proceedings of the International Symposium on Forest Seed Problems in Africa, Harare, Zimbabwe. Aug 23-Sept 2, 1987'. (Ed. S.K. Kamra and R.D. Ayling) pp. 84-94 (Swedish University of Agricultural Sciences, Umea, Sweden).

Eldridge, K.G. (1963). Effect of honey bees on seed production of Eucalyptus regnans. For. Tech. Pap. For. Comm. Vic. No. 13, pp 6-13.

Eldridge, K.G. 1985. Managed seed production - improved sources. Paper to Regional Seed Centre Workshop, Harare, Zimbabwe, July, 1985.

Ewart, A.J. (1908). On the longevity of seeds. Proc. R. Soc. Vic. 21, 1-210.

Fielding , J.M. (1956). Notes on the flowering and seeding of Eucalyptus delegatensis and E. fastigata in the Australian Capital Territory. Aust. For. 20, 40-3.

Florence, R.G. (1964). A comparative study of flowering and seed production in six blackbutt (Eucalyptus pilularis Sm.) forest stands. Aust. For. 28, 23-33.

Green, J.W. (1971). Variation in Eucalyptus obliqua L'Herit. New Phytol. 70, 897-909.

Grose, R.J. (1961). Some silvicultural characteristics and notes on the silviculture of alpine ash, Eucalyptus delegatensis R.T. Baker. 2nd World Eucalyptus Conf. Sao Paulo, Brazil. Vol. I pp. 704-14.

Grose, R.J. (1963) Silviculture of Eucalyptus delegatensis. Pt 1. Germination and seed dormancy. School of Forestry, University of Melbourne, Bulletin No. 2.

Grose, R.J. and Zimmer, W.J. (1985a). A description of the seeds of 70 Victorian eucalypts (illustrated). Bull. For. Comm. Vic. No. 8.

Grose, R.J. and Zimmer, W.J. (1985b). The influence of seed size on germination and early growth of seedlings of Eucalyptus maculata Hook. f. and Eucalyptus sieberiana F.v.M. Bull. For. Comm. Vic. No. 9.

Grose, R.J., and Zimmer, W.J. (1958c). The collection and testing of seed from some Victorian eucalypts with results of viability tests. Bull. For. Comm. Vic. No. 10.

Guldager, P. (1973). Seed problems related to direct sowing in pots. Proc. Internat. Symp. Seed Processing, Bergen, Norway, Vol. II, paper No. 12.

Hall, C. (1914). The evolution of the eucalypts in relation to the cotyledons and seedlings. Proc. Linn. Soc. N.S.W. 39, 473-532.

Hodgson, A. (1956). Some observations on the effect of moisture content on the resistance of Eucalyptus obliqua seed to heat maintained for varying lengths of time together with some preliminary investigations of temperatures in slash fires. M. Sc. Thesis, Univ. of Melbourne.

Hodgson, L.M. (1975). Some aspects of reproductive behaviour in Eucalyptus grandis (Hill) Maiden. D.Sc. Thesis, Univ. of Pretoria.

Hyland, B.P.M. (1972). A technique for collecting botanical specimens in rain forest. Bull. Flora Malesiana. No. 26. pp. 2038-40.

Midgley, S.J., Eldridge, K.G. and J.C. Doran (1987). Genetic resources of Eucalyptus camaldulensis. Paper to the Forestry/Fuelwood Research and Development (F/FRED) Project's meeting on multipurpose tree species research in the arid and semi-arid tropics, Karachi, Pakistan, 16-19 November 1987.

Jacobs, M.R. (1955). 'Growth Habits of the Eucalypts'. (Govt Printer: Canberra).

Kirkpatrick, J. (1975). Geographical variation in Eucalyptus globulus. Bull. For. Timb. Bur. Aust. No. 47.

Kleinig, D.A. and Boland, D.J. (1977). Use of .243 and .308 calibre rifles for eucalypt seed collections. Inst. For. Aust. Newslett. 18(3): 22-3.

Kleinig, D.A. and Doran, J.C. (1981). Eucalypt propagation on a small scale. Division of Forest research, CSIRO. Canberra 4pp.

Maiden, J.H. (1903-33). 'A Critical Revision of the Genus Eucalyptus'. (Govt Printer: Sydney).

Moran, G.F. and Bell, J.C. (1983). Eucalypts. In 'Isozymes in Plant Genetics and Breeding, Part B': (Eds). S.D. Tanksley and T.J. Orton (Elsevier Science Publishers B.V: Amsterdam.)

Ojo, G.O.A. and Jackson, J.K. (1973). Eucalyptus camaldulensis provenance trial at six years. In 'Tropical Provenance and Progeny Research and International Cooperation'. (Ed. J. Burley and D.G. Nikles). pp. 279-83. (Commonw. For. Inst: Oxford).

Pederick, L.A. (1960). Some seed collection data from adjacent trees of Eucalyptus obliqua L'Herit. For Tech. Pap. For. Comm. Vic. No. 5, pp. 19-24.

Pederick, L.A. (1976). The genetic resources of the Victorian eucalypts. Bull. For. Comm. Victoria No. 22.

Shrestha, K.B., Shepherd, K.R. and Turnbull, J.W. (1985). Controlled atmosphere storage for Pinus radiata seed. Commonw. For. Rev. 64(2).

Suiter, W. and Lisbao, L. (1973). Influence of relative humidity on the characteristics of the seeds of Eucalyptus saligna Sm. Proc. Internat. Symp. Seed Processing, Bergen, Norway, Vol. II. paper No. 10.

Turnbull, J.W. (1979) Geographic variation in Eucalyptus cloeziana. Ph.D. thesis. Australian National University.

Turnbull, J.W. and Griffin, A.R. (1984). The concept of provenance and its relationship to infraspecific classification in forest trees. In 'Infraspecific Classification of Wild and Cultivated Plants' (Ed. B.T. Styles.) The Systematics Association Special Volume No. 29 (Clarendon Press: Oxford).

Turnbull, J.W. and Doran, J.C. (1987). Seed development and germination in the Myrtaceae. Pages 46-57 in 'Germination of Australian Native Plant Seed'. Ed. P.J. Langkamp, (Inkata Press: Melbourne.)

White, B.J. (1971). Karri silvics. Res. Note for Dept. W. Aust. No. 1.

Wolf, L.J., and Turnbull, J.W. (1982). The computerised seed store record system of the CSIRO Tree Seed Centre, Australia. Forest Genetic Resources Information 11, 20-38.

Yacubson, D. (1961). Contribucion al estudio de las semillas de algunas especies de eucaliptos cultivades en la R. Argentina. 2nd World Eucalypt Conf. Sao Paulo, Brazil. Vol. I, pp. 268-84.

TREESEED : Version 1.0

WHAT IS IT?

A database management system used principally by the Australian Tree Seed Centre for the storage of seed information and accounting options. Potentially it has a wide range of other uses and can easily be adapted to other inventory systems.

WHO CAN USE IT?

This program is designed for use on microcomputers in the management of seed stores where provenance information and mother tree details are regularly used. The program is easy to use and has been designed particularly for those not familiar with computers. Clear instructions with examples are given in the user manual.

WHAT DOES IT DO?

Seed data such as species name, locality of collection, weight of seed and its viability are stored, as are details of transactions with customers.

Names of customers, countries, species and sponsor for despatch are accessed by codes which are determined by the user.

The storage and manipulation of records of multiple collections of seed from different sets of trees at the same locality are a feature of the program. Records from single trees are also accepted.

When interrogating the database, search criteria (based on the fields included in the database) are selected by the user; output is sent to the screen or printer.

The following databases are used by the program:

* accessions
* despatches
* customers
* countries
* plant genera
* plant species
* seed pre-treatments

Listings of their contents are easily obtained.

During the transaction procedure records are updated automatically. Despatch or consignment notes are prepared and printed during the transaction process. There is also an option to delay despatch note production.

Backup procedures are also a feature. All files are dumped on to floppy disks (1.2Mb or 360kb) using instructions presented by the program on the screen.

There is also the facility whereby all files may be restored from the backup floppy disks to the hard disk. Instructions for backup and restoration are easy to follow.

SOFTWARE

Program Name:	TREESEED, a management system for the maintenance of tree seed collections
Programmer:	Peter N. Martensz

Hardware and Software Requirements:

Computer model	IBM-compatible PC/AT, XT or PS2 microcomputers
Operating systems	DOS 2.0 or higher
Memory required	320kb
Disk drives required	1 hard drive and 1 floppy drive (to accept either 1.2Mb or 360kb floppy disks)
Printer required	Yes (must be capable of printing 120 characters on one line)

Additional information :

Developed at :	CSIRO Division of Forestry and Forest Products PO Box 4008, Queen Victoria Terrace A.C.T. 2600 Australia
Program available from :	Mr P.N. Martensz CSIRO, Division of Forestry & Forest Products PO Box 4008, Queen Victoria Terrace A.C.T. 2600 Australia
Media :	2 floppy disks and user's manual
Cost :	A$450 (Discount may apply to approved purchasers)

IX

EFECTO DE LA CONDICION DE LUZ EN LA PRODUCCION DE PLANTULAS DE *Eucalyptus globulus* A RAIZ DESNUDA Y RAIZ CUBIERTA (*)

René Escobar R. (**)
Miguel Espinosa B.(**)

RESUMEN

El efecto de la condición de luz (plena luz, semisombra hasta 7 días después de la emergencia y semisombra permanente) y tipo de planta (raíz desnuda y raíz cubierta) en la producción de plántulas de **Eucalyptus globulus** en vivero, fue evaluada a la cosecha, a través de la medición de variables morfológicas y contenido de nutrientes del follaje.

Con excepción de las variables altura de tallo y área foliar, las plantas a raíz desnuda tienden a disminuir sus dimensiones a medida que disminuye la disponibilidad de luz. Las plantas a raíz cubierta muestran una tendencia similar sólo en lo que respecta a diámetro de cuello, peso de raíces y peso total. De todas las variables morfológicas consideradas, existe similitud entre ambos tipos de plantas sólo en los valores de superficie foliar específica; en el resto de las variables, las plantas a raíz desnuda logran dimensiones mayores.

(*) Convenio de Investigación. Forestal Río Vergara. Universidad de Concepción.
(**) Departamento de Ciencias Forestales, Facultad de Ciencias Agropecuarias y Forestales. Universidad de Concepción, Casilla 537. Chillán - Chile.

INTRODUCCION.

En Chile tradicionalmente se ha producido plantas de Eucalyptus a raíz cubierta y bajo semisombra. Sólo recientemente se ha tendido a modificar la metodología de producción por plantas a raíz desnuda.

La producción de plantas a raíz cubierta es aconsejable utilizarla en especies altamente sensibles al transplante o que poseen un sistema radicular susceptible a la luz y al viento. En climas áridos, tropicales o subtropicales, caracterizados por altas tasas de evapotranspiración.

La semisombra es una labor cultural que se utiliza en vivero para disminuir la temperatura del suelo e intensidad de riego o para proteger plántulas de especies cuyo follaje es sensible a altas tasas de luminosidad en sus estados iniciales de crecimiento.

Estudiando en Eucalyptus globulus el efecto de época de siembra y semisombra hasta el 80% de la emergencia, Lema (1987) observó que las plantas producidas bajo condiciones de luz reducidas tenían tendencia a ser más delgadas y livianas que aquellas a plena luz. En este trabajo se analiza el efecto de tres distintas condiciones de luminosidad en plantas producidas a raíz desnuda y raíz cubierta.

MATERIAL Y METODO.

Las plantas utilizadas en este estudio fueron producidas en el vivero La Suerte, de propiedad de la Empresa Forestal Río Vergara S.A., ubicado a 3,5 km al sur de Nacimiento. El suelo del vivero es de textura franco-arenosa, con un punto de marchitez permanente de 18.5%, capacidad de campo de 31.8%, densidad aparente de 1.30 g/cm3 y humedad aprovechable de 207.5 m3/ha (en los primeros 12 cm de espesor del suelo). El pH es moderadamente ácido, con un nivel normal de Ca, medio de N-NO3 y bajo de materia orgánica, P, K, Mg y de capacidad de intercambio catiónico (Carrasco, 1987).

La siembra se efectuó en octubre de 1986 a una densidad de 500 semillas por metro lineal de platabanda distribuídas en 5 hileras y a una profundidad de 0.8 cm. Cuando las plántulas alcanzaron una altura promedio de 5 cm se ralearon a una densidad final de 20 plantas por hilera. La poda de la raíz principal se efetúo cuando tenían una altura de 20 cm, conjuntamente con dos delcalces a intervalos de 15 días entre ellos.

En la producción de plantas a raíz cubierta se utilizó una mezcla de 3 partes de suelo de vivero y una parte de arena, la que se depositó en bolsas de polietileno de 15 cm de largo por 6.5 cm de diámetro colocadas a 20 cm del suelo. Cinco semillas fueron sembradas en cada bolsa a una profundidad de 0.8 cm. La densidad se redujo a una planta por bolsa cuando la altura promedio de ellas era de 5 cm.

Para la producción de ambos tipos de plantas el suelo se desinfestó con una dosis equivalente a 6 kg/ha de Dexón, 3 kg/ha de PCNB y 4 kg/ha de Aldrín.

La fertilización consistió en una dosis equivalente a 150 kg/ha de N, 180 kg/ha de P2O5 y 150 kg/ha de K2O, en forma de urea, superfosfato triple y sulfato de potasa, respectivamente. Las dosis se aplicaron en cinco parcialidades iguales entre el período de pre-siembra y el término del acondicionamiento.

El riego se efectuó con una periodicidad determinada por la humedad aprovechable del suelo; el control de malezas se hizo mecanicamente.

Para determinar el efecto de la condición de luminosidad en la producción de plantas, se estableció un experimento consistente en cuatro bloques (repeticiones) y dos factores: tipo de planta (raíz desnuda y raíz cubierta) y condición de luminosidad (plena luz, semisombra hasta 7 días después de la emergencia y semisombra permanente). La intensidad de la luz fue reducida aproximadamente en un 50% por medio de una malla plástica (Raschel), ubicada a 2.5 m del suelo para semisombra permanente y a 1 m para sombra parcial.

El diseño experimental utilizado es el de parcela dividida, ubicándose a nivel de tratamiento el tipo de planta y en las parcelas menores o subparcelas las distintas condiciones de luminosidad.

En la segunda semana de Junio de 1987, 8 meses después de la siembra, se cosechó en cada subparcela 25 plantas elegidas al azar, de las cuales 5 se utilizaron en el análisis fitoquímico. En las 20 restantes se midieron diez variables morfológicas: largo de tallo (cm); diámetro de cuello (mm); peso seco de tallo (incluye peso de hojas (g); peso seco raíces secundarias menor a 1 mm (g); peso total de raíces (g); peso total planta (biomasa); superficie foliar específica (cm2/g); superficie foliar (cm2) y las relaciones largo de tallo-diámetro de cuello y peso de tallo-peso de raíz. El largo de tallo se midió con precisión de 0,5 cm; diámetro de cuello con precisión de 0,1 mm; los pesos secos con precisión de 0,01 g después de secar con aire forzado por 24 hrs a 105°C.

La superficie de las hojas se determinó con un medidor de superficie Li-Cor Li-3000 de submuestras de hojas verdes de cuatro plantas por subparcela. La superficie foliar proyectada (un lado) de las plantas fue obtenida multiplicando el peso seco de las hojas por la superficie foliar específica (superficie de las hojas verdes por peso seco de las hojas) (Espinosa et al. 1987).

A través de análisis foliar se determinó los contenidos de N, K, Ca, Mg, Fe, Cu, Mn y Zn, utilizando la metodología de Lachica et al. (1985).

Los datos obtenidos para cada tipo de planta fueron sometidos a un análisis de varianza para un diseño de parcela dividida. Este procedimiento determina la significancia de los efectos principales o interacciones de los factores incluidos en el análisis. Si la interacción de los factores es significativa, los efectos principales de los factores no tienen relevancia, independientemente de que ellos sean o no significativos, ya que implica que estos no actúan independientemente uno del otro (Petersen, 1976). Este procedimiento se sigue en el texto para el análisis de las variables morfológicas consideradas.

RESULTADOS Y DISCUSION.

Características Morfológicas.

En la Tabla 1 se presentan los valores promedios por tipo de planta y condición de luminosidad para las distintas variables morfológicas analizadas. El grado de significancia de los factores principales e interacciones en la Tabla 2.

Largo de tallo.

Las plantas producidas a raíz desnuda logran mayor crecimiento en altura que las plantas producidas a raíz cubierta y sobre el nivel del suelo en una proporción cercana

TABLA 1. VALORES PROMEDIOS PARA LAS DISTINTAS VARIABLES MORFOLOGICAS EN PLANTAS DE EUCALYPTUS GLOBULUS PRODUCIDAS A RAIZ DESNUDA Y RAIZ CUBIERTA BAJO DISTINTAS CONDICIONES DE LUMINOSIDAD.

VARIABLES MORFOLOGICAS		RAIZ DESNUDA				RAIZ CUBIERTA			
		CONDICIONES DE LUZ							
		A	B	C	Media Trat.	A	B	C	Media Trat.
1. Altura de tallo	cm	103.62	98.96	103.01	101.86	29.26	35.43	42.43	35.71
2. Diámetro de cuello	mm	10.26	8.84	7.90	9.00	3.55	3.60	3.26	3.47
3. Altura/diámetro		10.16	11.21	13.08	11.48	8.26	9.83	13.01	10.37
4. Peso seco tallo	g	26.58	20.95	16.45	21.33	2.51	2.55	2.09	2.38
5. Peso seco raíces < 1 mm	g	1.55	1.22	0.86	1.21	0.60	0.49	0.33	0.48
6. Peso total raíces	g	5.05	4.16	2.82	4.01	0.85	0.73	0.51	0.69
7. Peso tallo/peso raíz		5.29	5.09	5.81	5.39	2.95	3.51	4.15	3.53
8. Peso total (Biomasa)	g	31.63	25.11	19.27	25.34	3.36	3.28	2.60	3.08
9. S. foliar específica	cm2/g	129.50	144.26	191.84	155.20	111.63	131.33	191.74	144.90
10. Area foliar	cm2	1399.36	1184.28	1308.84	1297.49	192.61	218.34	244.80	218.58

A = Plena luz

B = Semisombra hasta 7 días después de emergencia

C = Semisombra permanente

a 3 (Tabla 1). Sin embargo, la condición de luminosidad parece no ser determinante en la altura que alcanzan las plantas a raíz desnuda al momento de la cosecha. En cambio, en plantas a raíz cubierta existe una clara tendencia a un mayor crecimiento en la medida que disminuye la cantidad de luz (Fig. 1a). La interacción de ambos factores es significativa (Tabla 2).

La relación entre el grado de luminosidad y la disponibildad de agua en el suelo puede explicar el comportamiento diferente de las plántulas producidas en bolsa. Cualquier material que interfiera la radiación luminosa directa sobre el suelo genera una mayor conservación de la humedad, especialmente en los primeros centímetros de él (Stoeckler, 1965). Las plantas producidas a raíz cubierta disponen de un reducido volumen de suelo para efectuar sus procesos vitales; en cambio, en la producción a raíz desnuda la planta, bajo condiciones de estrés hídrico, tiene la posibilidad de explorar un mayor volumen de suelo. La humedad del suelo del vivero, como lo demostró Aruta (1985) en pino radiata, es determinante en los estados iniciales de crecimiento de las plantas. Eucalyptus globulus es una especie extremadamente sensible a la disponibilidad de agua en el suelo (Escobar y Espinosa, 1987).

TABLA 2. RESUMEN ANALISIS ESTADISTICO PARA LAS DISTINTAS VARIABLES MORFOLOGICAS EN PLANTAS DE EUCALYPTUS GLOBULUS PRODUCIDAS A raíz DESNUDA Y raíz CUBIERTA BAJO DISTINTAS CONDICIONES DE LUMINOSIDAD.

VARIABLES MORFOLOGICAS	RESPUESTA DE LAS PLANTAS A LA VARIABLE		
	Tp	Cl	Tp*Cl
Altura de tallo	**	*	*
Diámetro de cuello	**	**	*
Altura/diámetro	*	**	N.S.
Peso seco tallo	**	**	**
Peso seco raíces <1mm	**	**	N.S.
Peso total raíces	**	**	*
Peso tallo/peso raíz	**	*	N.S.
Peso total (Biomasa)	**	**	*
S. foliar específica	N.S.	**	N.S.
Area foliar	**	N.S.	N.S.

Tp = tipo de planta; Cl= condición de luminosidad.
NS = no significativo; * = P '0.05; ** = P '0.01.

Diámetro de cuello.

Las plantas producidas a raíz desnuda logran un diámetro considerablemente mayor que las plantas producidas a raíz cubierta (Tabla 1). Ello podría deberse, en parte, a un problema de competencia, dadas las características de producción de este tipo de planta y de los receptáculos utilizados los que deben permanecer contiguos uno de otro.

El efecto de la intensidad luminosa es consistente en el crecimiento en diámetro de las plantas producidas a raíz desnuda; las que crecen a plena luz logran casi un 20% más que las que tuvieron sombra por siete días y practicamente un 30% más que las que permanecieron bajo sombra permanente. En las plantas producidas a raíz cubierta la tendencia no es tan clara; no obstante, las plantas que permanecieron bajo sombra permanente logran valores más reducidos que aquellas con mayor grado de luminosidad (Fig. 1b).

El análisis estadístico para esta variable mostró que la interacción tipo de planta x condición de luminosidad era significativa (Tabla 2), indicando que una disminución de luminosidad causa una reducción del crecimiento en diámetro en ambos tipos de plantas.

Relación altura/diámetro.

Las plantas que crecieron en una condición de plena luz logran una menor relación altura/diámetro que aquellas expuestas a algún grado de sombra (Tabla 1, Fig. 1c). En las plantas a raíz desnuda no hay mayor efecto de la condición de luz en su altura, no así en diámetro. En este caso la menor disponibilidad de luz afecta negativamente el diámetro de las plañtulas, situación que genera un valor mayor de la relación, dando origen a una planta más descompensada.

Los valores logrados podrían reducirse aplicando esquemas de acondicionamiento más rigurosos que el utilizado en este estudio, tendiente a controlar el crecimiento en altura sin afectar el crecimiento en diámetro, como lo demostraron Sánchez (1987) y Escobar y Espinosa (1987) con esta especie.

En las plantas a raíz cubierta hay un efecto menos pronunciado de la condición de luz en el diámetro, aunque no en altura. Esto determina una relación mayor a medida que disminuye la disponibilidad de luz.

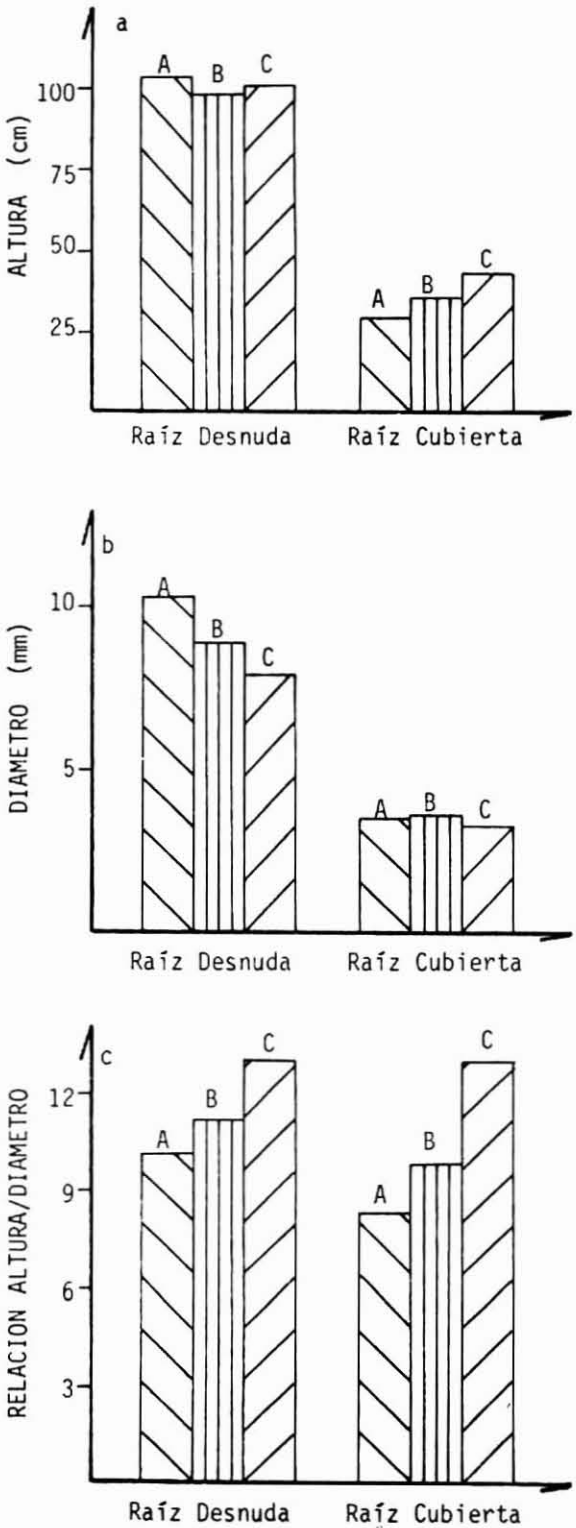

Fig 1: Altura, Diámetro de cuello y Relación altura/diámetro de plantas producidas a raíz desnuda y raíz cubierta bajo diferentes condiciones de luminosidad (A, plena luz; B, sombra hasta 7 dias después de la emergencia; C, sombra permanente).

A diferencia de las variables altura y diámetro, la relación entre ellas no muestra significancia para la interacción tipo de planta x condición de luminosidad, siendo este último factor altamente significativo (Tabla 2).

Peso seco de tallo.

El peso del tallo de las plantas producidas a raíz cubierta es casi 10 veces menor que el de las producidas a raíz desnuda. En este tipo de plantas hay un claro efecto negativo del empleo de semi sombra: las de plena luz pesan 10 g más que bajo sombra permanente y casi 7 g más que aquellas que tuvieron sombra hasta una semana después de la emergencia (Tabla 1).

En las plantas a raíz cubierta no hay una tendencia tan clara respecto al efecto de la disponibilidad de luz en el peso seco del tallo. Sin embargo, las plantas producidas bajo sombra permanente pesan aproximadamente un 25% menos que las de los otros niveles del factor, aunque tienen mayor altura (Tabla 1).

El peso del tallo muestra, para ambos tipos de plantas, una tendencia similar al diámetro de cuello de las plantas (Figs. 1b y 2a). Similar observación fue formulada por Sánchez (1987) en un ensayo de diferentes esquemas de acondicionamiento en <u>Eucalyptus globulus</u>.

El análisis estadístico (Tabla 2) indica una alta significancia para la interacción tipo de planta x condición de luminosidad, lo que implica que tanto el tipo de planta como la condición de luz son determinantes en el peso del tallo.

Peso de raíces secundarias menores de 1 mm de diámetro.

Las plantas a raíz desnuda producen 2,5 veces más masa de raíces finas que las a raíz cubierta (Tabla 1), fundamentalmente por la mayor disponibilidad de espacio vital y por el beneficio que en este tipo de plantas produce el acondicionamiento (Escobar y Espinosa, 1987; Sánchez, 1987). En plantas a raíz cubierta, por el hecho de ser producidas sobre el nivel suelo, el 100% de la masa radicular está constituída por raíces menores a 1 mm de diámetro.

Tanto en plantas a raíz desnuda como a raíz cubierta hay una marcada disminución de la masa de raíces finas en la medida en que se reduce la disponibilidad de luz

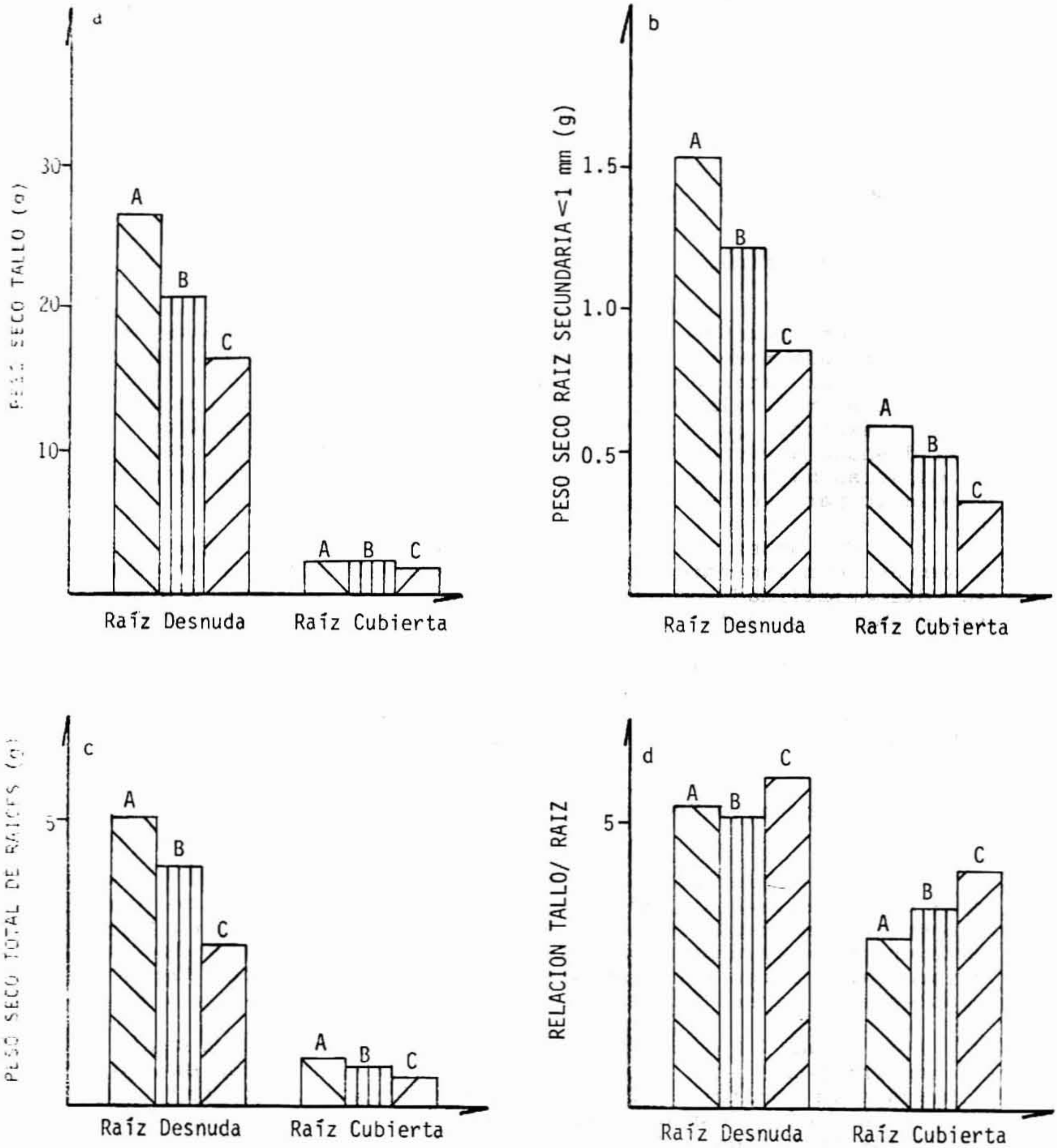

Fig 2: Peso seco de diferentes componentes de las plantas producidas a raíz desnuda y raíz cubierta bajo diferentes condiciones de luminosidad (A, plena luz; B, sombra hasta 7 dias después de la emergencia; C, sombra permanente).

(Fig. 2b). Este fenómeno es de capital importancia, por cuanto este tipo de raíz es el que participa en mayor grado en la absorción de agua y nutrientes (Hobbs, 1984).

El análisis estadístico (Tabla 2) muestra que se producen diferencias altamente significativas para ambos factores, no así su interacción, indicando que el tipo de planta no influencia la reacción de las mismas a la condición de luminosidad en que se desarrollen en el vivero.

Peso total de raíces.

Las plantas a raíz desnuda producen un sistema radicular casi 6 veces mayor que el de plantas a raíz cubierta (Tabla 1). En estas últimas, aproximadamente el 70% del peso del sistema radicular esta constituido por raíces menores a 1 mm de diámetro, porcentaje que en el caso de las plantas a raíz desnuda asciende a un 30%. El resto corresponde a raíces secundarias mayores a 1 mm y al peso de la raíz principal, necesario para sustentar plantas de mayor tamaño.

En ambos tipos de plantas, y al igual que lo observado con las raíces absorventes, a medida que disminuye la disponibilidad de luz es menor el peso del sistema radicular (Fig. 2c).

El análisis estadístico (Tabla 2) muestra que la interacción tipo de planta x condición de luminosidad era significativa (P'0.05), indicando que el tipo de planta influencia la reacción de éstas a la disponibilidad de luz.

Relación Peso tallo/Peso raíz.

La relación entre el peso de la parte aérea y la masa radicular, una medida del balance entre el área de transpiración (tallo) y el área de absorción de agua y nutrientes (raíz) de las plantas (Thompson, 1984), alcanza valores superiores en plantas a raíz desnuda, producto de las mayores dimensiones de los componentes (Tabla 1).

Las plantas a raíz cubierta incrementan consistentemente los valores de esta relación a medida que disminuye la condición de luz, situación no tan marcada en plantas a raíz desnuda (Fig. 2d). Esto sugiere que bajo reducidas condiciones de luz la estrategia de crecimiento de las plantas es incrementar la producción de la parte aérea en desmedro de la masa radicular, dando origen a plantas más desbalanceadas. Reed et al. (1983) determinó en plántulas de pino oregón sometidas a diferentes niveles de luminosidad y fertilización nitrogenada, que la relación tallo/raíz decrecía con el incremento de la luminosidad. Esta es una respuesta conocida (e.g., Lavender et al., 1968).

Como muestran las Figuras la y 2d, se aprecia una tendencia similar entre la altura de las plantas y la relación tallo/raíz según sea la condición de luminosidad, sugiriendo que ambas variables podrían relacionarse, lo que deberá determinarse en estudios posteriores.

El factor tipo de planta es altamente significativo, siendo significativa la condición de luminosidad (Tabla 2). La interacción no es significativa, indicando con ello que el tipo de planta no influencia la respuesta de estas al factor luz.

Superficie foliar específica.

La superficie foliar específica (cm2 de superficie de hoja por gramo de peso seco de hoja), a diferencia del resto de las variables morfológicas analizadas, presenta valores muy similares entre los dos tipos de planta producida (Tabla 1). Tanto aquellas a raíz desnuda como a raíz cubierta son significativamente afectadas por la condición de luminosidad (Tabla 2), siendo esta dependencia más acentuada a medida que incrementa el nivel de sombra. De esta forma, las plántulas de eucalipto han respondido a una menor disponibilidad de luz cambiando la anatomía de la hoja, esto es, incrementando la relación superficie de hoja/peso de hoja. Cole and Newton (1986) obtuvieron una respuesta similar en una plantación de pino oregón de 5 años de edad creciendo bajo competencia por luz.

La tendencia observada de las plántulas de incrementar su superficie foliar específica con la disminución de la condición luminosa, es similar a la experimentada por la relación altura/ diámetro ante una variación de este factor (Figs. 1c y 3a). Estudios futuros pueden determinar una posible relación entre estas variables.

Area foliar.

Las plantas a raíz desnuda logran una superficie foliar casi 6 veces superior a las producidas en bolsa (Tabla 1). Las alturas superiores de este tipo de planta implican una mayor masa de hojas lo que se refleja en valores más altos

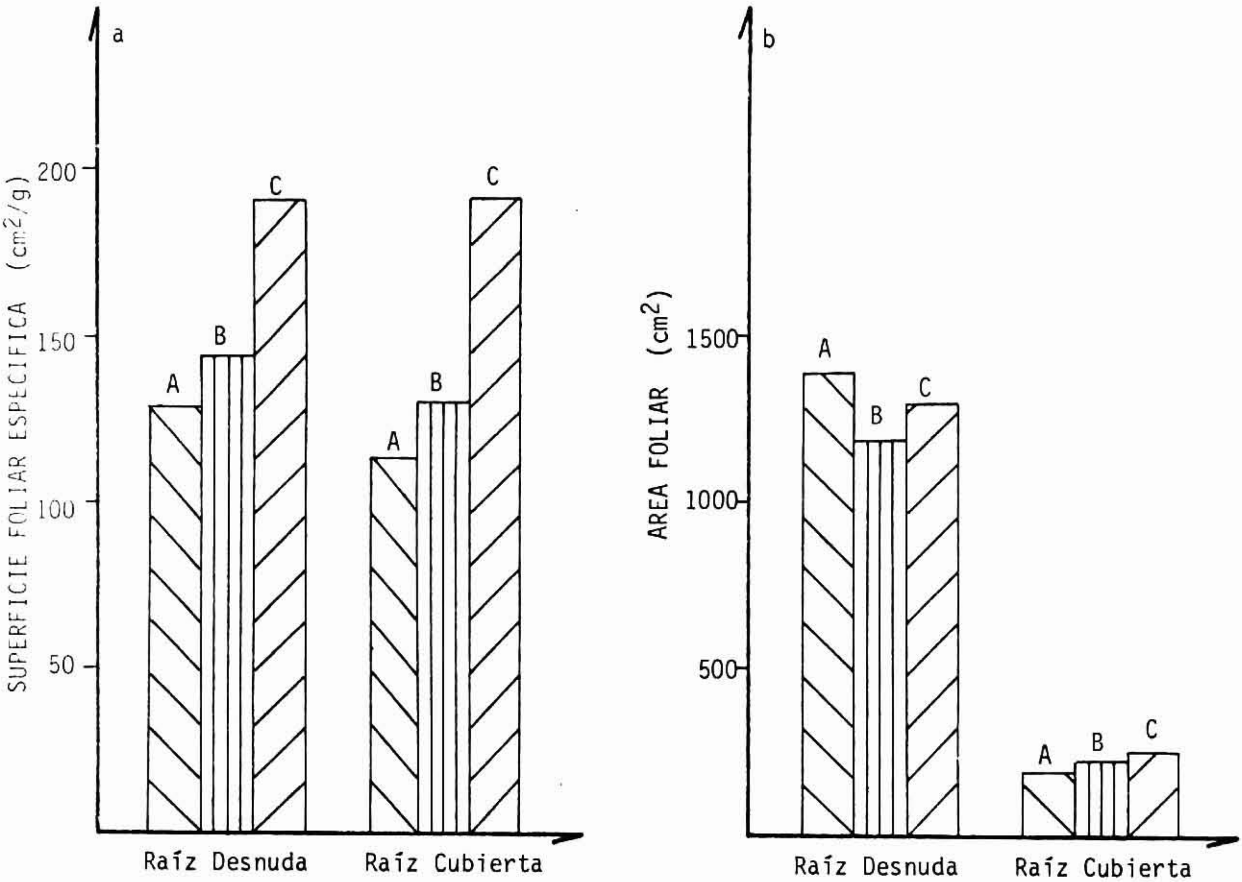

Fig 3: Superficie Foliar Específica y Area Foliar de plantas producidas a raíz denuda y raíz cubierta bajo diferentes condiciones de luminosidad (A, plena luz; B, sombra hasta 7 dias después de la emergencia; C, sombra permanente).

para esta variable. El área foliar - representativo del potencial fotosintético de que disponen las plantas - guarda estrecha relación con el tipo de planta producida, siendo este factor altamente significativo (Tabla 2).

Como se aprecia en la Figura 3b, no hay una tendencia única para plantas a raíz desnuda y a raíz cubierta con respecto a la condición de luminosidad. La literatura respectiva destaca este hecho, indicando la disimilitud en la respuesta de las hojas a la mayor o menor disponibilidad de luz (Isanogle, 1944; Logan, 1970; Tsel}niker, 1977; McClendon and McMillen, 1982; Nygren and Kellomaki, 1983, citados por Goulet and Bellefleur, 1986).

Característica Fisiológica.

Contenido de nutrientes en el follaje.

La Tabla 3 muestra los contenidos de distintos elementos en el follaje de plantas producidas a raíz desnuda y raíz cubierta para las distintas condiciones de luminosidad probadas en el ensayo.

En plantas a raíz desnuda, los contenidos de N, P y Fe en el follaje no muestran tendencias claras al efecto de la luz. Cinc tiende a disminuir a medida que disminuye la disponibilidad de luz, al contrario de calcio y manganeso. Potasio y magnesio tienen un comportamiento similar (Tabla 3).

Los niveles nutricionales de N y P son considerablemente mayores que los obtenidos por Sánchez (1987) en su estudio sobre acondicionamiento de plantas de Eucalyptus globulus a raíz desnuda. Lo contrario ocurre con el elemento calcio, el que alcanza niveles más altos.

TABLA 3. CONTENIDO DE DIFERENTES ELEMENTOS EN EL FOLLAJE DE PLANTAS DE EUCALYPTUS GLOBULUS PRODUCIDAS A raíz DESNUDA (RD) Y raíz CUBIERTA (RC) BAJO DISTINTAS CONDICIONES DE LUMINOSIDAD.

	N	P	K	Ca	Mg	Fe	Cu	Mn	Zn
			%				ppm		
RD A	2.58	0.20	1.12	0.76	0.25	356	12	266	31
RD B	2.89	0.26	1.12	0.85	0.25	236	12	348	21
RD C	2.61	0.21	1.26	1.05	0.32	423	12	356	20
RC A	2.46	0.21	1.26	0.54	0.16	252	11	357	27
RC B	2.83	0.26	1.30	0.64	0.18	254	15	366	25
RC C	2.92	0.30	1.39	0.66	0.24	294	17	343	27

A = Plena luz; B = Semisombra hasta 7 días después de emergencia; C = Semisombra permanente.

En plantas producidas a raíz cubierta, todos los elementos, con exepción de Mn y Zn, incrementan los niveles en el follaje a medida que disminuye la condición de luminosidad (Tabla 3). Reed et al. (1983) encontró que la concentración foliar de este elemento tendía a decrecer con el incremento de la disponibilidad de luz para un nivel dado de N en plantas de pino oregón.

CONCLUSIONES.

- Las plantas producidas a raíz desnuda logran mayor altura, diámetro de cuello, peso seco de tallo, peso seco de raíces finas, peso total de raíces y área foliar que las plantas producidas a raíz cubierta.

- La disponibilidad de luz no es determinante en la altura de las plantas producidas a raíz desnuda. En plantas a raíz cubierta, la altura de estas aumenta en la medida que disminuye la disponibilidad de luz.

- El uso de sombra en Eucalyptus globulus afecta negativamente el diámetro de cuello, peso seco de tallo, raíces finas, total de raíces y biomasa.

- Las plantas producidas a plena luz, logran valores menores en la relación peso seco de tallo/peso de raíces y altura/ diámetro. Son más balanceadas que las que utilizan semisombra.

- La superficie foliar específica es mayor en plantas producidas bajo sombra. Se incrementa el valor de la relación superficie/peso de hoja.

- En plantas producidas a raíz cubierta los niveles de N P K Ca Mg Fe y Cu aumentan en el follaje, en la medida en que disminuye la disponibilidad de luz.

BIBLIOGRAFIA.

1. ARUTA, F. 1982. Determinación de uso de consumo de Pinus radiata D. Don en condiciones de vivero. Universidad de Concepción. Fac. Cs. Agrop. y Forestales. Depto. de Ciencias Forestales (Tesis mimeografiada).

2. CARRASCO, P. 1987. Caracterización de suelos del vivero La Suerte. Convenio Universidad de Concepción - Forestal Ró Vergara. Proyecto 20.20.06 (no publicado).

3. COLE, E. and NEWTON, M. 1986. Nutrient, moisture and light relations in 5 year-old Douglas-fir plantations under variable competition. Can. J. of For. Res. 16:727-732.

4. ESCOBAR, R. y ESPINOSA, M. 1987. Efecto de la interacción acondicionamiento-riego-fertilización en el comportamiento de plantas de Eucalyptus globulus. Convenio Universidad de Concepción-Forestal Río Vergara, Proyecto 20.20.06. Chillán (no publicado).

5. ESPINOSA, M.; PERRY, D. and MARSHALL, J. 1987. Leaf-area sapwood area relationshipis in adjacent young Douglas-fir stands with different early growth rate. Can. J. of For. Res. 17(2): 174-180.

6. GOULET, F. and BELLEFLEUR, P. 1986. Leaf morfology plasticity in response to ligth environment in deciduos tree species and its implications of forest succession. Can. J. of For. Res. 16: 1192-1195.

7. HOBBS, S. 1984. The influence of species and stocktype selection on stand establishment: and Ecophysiological perspective. IN: Duryea, M. and Brown, G.(Eds.). Seedling physiology and reforestation succes (179-224). Martinus Nijhoff/Dr. Junk Publishers, The Hagne / Boston/ Lancaster. For. Res. Lab., Ore. St. Univ. Corvallis. U.S.A.

8. LACHICA, M. et al. 1985. Análisis de tejidos e interpretación de resultados. IN: Lachica, M. y González, C. (Eds.) Nutrición vegetal: algunos aspectos químicos y biológicos. (101-150). Est. Exp. del Zaidín-Granada. Fac. Cs. Químicas y Farmacéuticas. UNESCO.

9. LEMA, M. 1987. Epoca de siembra y efecto de semisombra en la producción de plantas de Eucalyptus globulus Labill. ssp. globulus 1/0 a raíz desnuda, Universidad de Concepción, Fac. Cs. Agrop. y For., Depto. Cs. Forestales. (Tesis mimeografiada). Chillán. 103 p.

10. LAVANDER, D.; CHING, K. and HERMANN, R. 1968. Effects of environment on the development of dormancy and growth of Douglas-fir seedlings. Bot. Gaz. 129: 70-83.

11. PETERSEN, G. 1976. Experimental designs for agricultural researsh in developing areas. O.S.U. Book Stores, Inc. Corvallis, Oregon.

12. REED, K. et al. 1983. Evaluation of interaction of two environmental factors affecting Douglas-fir seedling growth: ligth and nitrogen. Forest Science. 29(1): 193-203.

13. SANCHEZ, V. 1987. Esquemas de acondicionamiento en plantas de Eucalyptus globulus Labill. ssp. globulus 1/0 producidas a raíz desnuda. Universidad de Concepción, Fac. Cs. Agrop. y For.,Depto. Cs. Forestales (Tesis mimeografiada). Chillán. 86p.

14. STOECKELER, J. 1965. Conifer nursery practice in the prairie-plains. U. S. Dep. Agr., Agr. Handb. 279. 93 pp. illus.

15. THOMPSON, G. 1976. Clonal reforestation: forest of the future?. IN: Duryea, M. and Brown, G.(Eds.). Seedling physiology and reforestation succes (179-224). Martinus Nijhoff/Dr. Junk Publishers, The Hagne / Boston/ Lancaster. For. Res. Lab., Ore. St. Univ. Corvallis. U.S.A.

FERTILIZING EUCALYPTS AT PLANTATION ESTABLISHMENT

A.P.G. Schönau (*)
M.A. Herbert (*)

ABSTRACT

The results of field experiments in fertilizer research with Eucalyptus species at time of planting are reviewed, the oldest trial dating back to 1946. The responses of 33 species in 19 different countries to fertilizer application are given, together with the considerable increase in evidence over the last two decades of their impact on yields at clearfelling. The main deficiencies of micro - and macro-nutrients are briefly described and the detrimental effects of whole tree harvesting, burning and short rotations on the nutrient capital of a site are pointed out. The type of nutrient and fertilizer, and time and method of application are discussed briefly. The magnitude and maintenance of responses to fertilizer application and their economic profitability are indicated. Furthermore, the role of fertilizers, the functions of the main nutrients, and fertilizer-site and species interactions are discussed. Guidelines for monitoring and explaining fertilizer responses by means of enumeration, foliar sampling, regression analysis and response surfaces are given. In conclusion recommendations are made concerning general fertilizer requirements for different conditions of site and silviculture, together with the prerequisites of sound experimental techniques for obtaining meaningful research results and optimizing fertilizer practices.

(*) Institute for Commercial Forestry Research. University of Natal, Pietermaritzburg - South Africa.

INTRODUCTION

Eucalyptus species have generally evolved in geologically ancient landscapes and many species are adapted to withstand long periods of hot and dry weather. They are more efficient than most other forest species in conserving nutrients through intensive internal recycling and many can grow on sites of low fertility (Cromer 1984). Thus, on well-weathered soils possessing a low nutrient status plantation eucalypts often show a very rapid growth and healthy appearance where the climatic conditions and soil physical characteristics are favourable. The early success of eucalypt plantations under these conditions outside their original habitat may be the main reason that investigations into fertilizing eucalypts started relatively late.

However, during the last two decades the increase of investigations into fertilizer requirements of eucalypts has been tremendous. This is evident from the number of references cited by authors reviewing this subject, i.e. Baule and Fricker (1970) listed only five, Mello et al (1970) listed nine, Schutz (1976) 19, Balloni (1978) 24 and Schonau (1984 a) 63. These were general, worldwide reviews while Sinha (1970) gave 6 references in a regional review for India and Schonau (1983) 27 for Southern Africa. The success of many of these investigations resulted in a considerable increase in the use of fertilizers when establishing new eucalypt plantations and it has now become almost standard practice in countries such as Brazil, South Africa and New Zealand.

The object of this paper is to review the experimental evidence of response to fertilizer in eucalypts, its magnitude and maintenance, as well as methods and time of application. It will deal mainly with fertilizing at planting and will concentrate on field conditions , little reference being made to laboratory tests with seedlings or trials in nurseries. In addition a brief overview will be given of deficiency symptoms in the field and the economic consequences of fertilizing. Furthermore, the role of fertilizers and some nutrients in stand development and their interactions with site and the silviculture of plantations will be discussed. In conclusion general recommendations for various conditions as well as expected responses, profitability and guidelines for specific research will be given.

EXPERIMENTAL EVIDENCE

Responses to fertilizer application

Apparently the first fertilizer trials with eucalypts were carried out as far back as the 1930's in New Zealand (Ballard, 1978) but, unfortunately, records of these successful early trials were lost. The earliest documented fertilizer trial was laid down in 1946 in Madagascar with E.robusta (Dommergues, 1953). In this case transplants were raised in pots filled 33% with organic fertilizer (stable dung). These transplants were planted out in four replications and compared with untreated plants. Five years after planting the height growth of the former was on average 55% more than of the untreated controls.

Since then fertilizer experiments with more than 30 different eucalypts have been carried out in more than 17 countries, mainly in Africa, Australia, Latin America and In Mediterranean countries,but also in India, the USA and France. However, more than a third of the references are in respect of E.grandis and E.saligna, 12 for E.globulus ssp globulus, 7 for E.delegatensis and 6 for E.camaldulensis and E.tereticornis each , 3 each for E.citriodora, E.diversicolor and E.gomphocephala while the other species are mentioned only once or twice.The main species will be dealt with seperately below while the others will be treated under their sub-genera in taxonomical order.

Eucalyptus grandis and E.saligna

These two species are treated together since they are very similar and identification in the earlier literature has often been confused and incorrect.The earliest recorded experiment with E.grandis was laid out in 1952 in Zululand, South Africa (Lckhoff, 1955). It tested the application of P in the form of superphosphate, but no response was obtained,probably owing to late application mixing of the fertilizer with the soil and use of the wrong fertilizer. Subsequently it was shown that the demand was for N on similar sites which are low in organic matter and N (Schonau 1983).

The response of E.grandis and E.saligna during the first 18 months after application are mainly to P as indicated for Brazil (Melli,1968;Mello et al,1970; Simoes et al,1972; Rezende et al 1982; Mattos and Maciel, 1984), South Africa (Heiberg-Iurgensen and Pennefather, 1966; Pennefather and MacGillivray, 1971; Schonau and Pennefather, 1975), USA (Meskimen and Franklin, 1977) and Nigeria (Kadeba, 1978). The South African authors and Mello, (1968) also indicated an additive response to K.

In the USA the only response was to N (Barros and Pritchett, 1979). In Brazil, Mello (1968) noted also a response to N, additive to that for P while Knudson et al (1970) indicated that the response to N was greater than that to P which was additive. Similarly McIntyre and Pryor (1974), Cromer et al (1981) and Ward et al (1985) in Australia, Mhr et al (1969), Ranwell et al (1974) and Schonau (1977 a) in Southern Africa and Kadeba (1978) in Nigeria found that a combination of N and P gave the best response.Major responses to K have been reported from Madagascar (Malvos, 1983) and South Africa (Herbert, 1983), but the best response being to a combination of N, P and K. The latter result has been reported also by Dicks et al (1965), Mhr et al (1968) and Ranwell (1975).

In many instances no indications of the nutrient requirements of responding trees could be given since NPK mixtures were used (Brasil Sobrinho et al (1963), Simoes et al (1972) and Rezende et al (1982) in Brazil, Cooling and Jones (1970),and Hans and Burley (1972) in Zambia, Cannon (1984) in Colombia, and Schonau et al (1981), Herbert et al (1982), Mackenzie and Donald (1982), Schonau and Boden (1982) and Boden (1984) in

South Africa.It must be noted that the last author used different mixtures for different methods of site preparation due to a better understanding of the interaction between the latter and fertilization.

Applications of Ca and Mg to E.grandis/saligna have been studied much less than those of the three major nutrients.Generally these applications have shown no response on tree growth (Mello et al,1970; Schonau 1977 a) or showed a depressive effect (Herbert,1983;Schonau and Herbert, 1982; 1983). However,the latter have shown significant responses to applications of dolomitic lime in two experiments.interactions with K and N revealed thatt lime was only effective when applied together with K or when the application of N was omitted.

Eucalyptus globulus ssp globulus

Responses of E.globulus to fertilizer have been reported from Australia, Portugal,Spain,Colombia and discussed in India. Most of the responses were to N alone or to N and P combined, seldom to P applications on its own.No conclusions about the required nutrients can be made for Spain since compressed NPKCaMg tablets were used (Temes and Santiago, 1977) or for Colombia (Cannon, 1984) where a NPK mixture was used.In Portugal the responses were to N+P (Vieira de Brito, 1979), being very large,but it must be pointed out that these applications were more or less made annually.
Early work in Australia pointed to N as the main fertilizer for E.globulus, although in some trials there was a slightly better response to N+P,the latter on its own being not effective (Cromer, 1971). Flinn (1976) also described a response to N only, this being probably caused by the high P levels of the soil (900 mg/kg).

Cromer et al (1975, 1983), Cromer and Williams (1982) and Cromer (1984) described inter alia the progress of one experiment up to nine and a half years of age where the response to N+P was still increasing appreciably.These results were also mentioned by Bardhan Roy (1976). The requirement for N and P fertilizers by E.globulus was confirmed by Esparcia (1983) who undertook a nutrient content study with this species. Cromer et al (1981) reported on three trials where a single seedlot was used.At five years of age the response on two sites was to N only, while that on the third site was mainly to P with an additive response to N which was ineffective on its own. In other words the nature of response was determined by site factors and not by species or genotype.

Eucalyptus delegatensis

Fertilizer trials with E.delegatensis have primarily been undertaken in Australia and New Zealand but also in Spain. Cromer (1971) indicated that this species in early trials responded to N but not to P. Ballard (1978) quotes that in New Zealand this species benefitted in a 1960 trial from N and P applications in the form of blood and bone. Two years after planting the height increment of the treated trees was still twice that of the untreated controls.The same author states that this organic fertilizer was used throughout the 1960's and early 1970's but that trials in 1972 showed the superiority of an application of 57g. urea per tree which became standard practice. McKimm and Flinn (1979) showed that the main demand by this species in Victoria was for N in the form of urea and that additional P increased this response only slightly but was not considered economical. Ellis et al (1985) also found that the poor growth of E.delegatensis seedlings on grassland in Tasmania was caused by N deficiency. This was mainly ascribed to a low rate of mineralization of N and to competition for N by grass and associated vegetation. Bowman and Kirkpatrick (1986) showed in a combined site preparation fertilizer experiment also in Tasmania that fertilizing this species with Osmocote,a (NPK) show-release fertilizer was additive to the effect from removal of root competition by the old forest trees. However, the results suggested that the main competition was for moisture and not nutrients. Cromer (1984) quotes that the growth rate of seedlings of inter alia E.delegatensis is directly related to nutrientt uptake rate.In Spain, Temes and Santiago (1977) found that the application of compressed NPKCaMg tablets increased the height growth of this species in 22 months by 39%.

Eucalyptus camaldulensis

Successful trials with E.camaldulensis have been undertaken in the USA (Meskimen, 1971; Meskimen and Franklin,1977),Australia (Cameron et al , 1983), Madagascar (Malvos, 1983),Morocco (Lepoutre and Mandouri,(1976) and Nigeria (Kadeba, 1978). Meskimen used a blended tablet bonded with urea-formaldehyde resin consisting mainly of N (74%) with added amounts of P (9%),K (9%),S (5%),Fe (2,5%) and Zn (0,5%) with a lasting response up to 4 years. Meskimen and Franklin used rock phosphate, but the initial response at 2+ years had virtually disappeared at six years. Under irrigation Cameron et al (1983) found that the main nutrient requirement was for N with a smaller additive need for P.None of the other nutrients tested,i.e. K, Mg, S, Fe, Zn, Mn, Cu, B and Mo showed a significant response or interation.In Madagascar the main responses were to P and K which were additive in ripped and ridged land. In Morocco the demand of E.camaldulensis was mainly for P with some additional response to N.Kadeba (1978) showed in Nigeria that the best seedlings were raised when N and P were added to a nursery mixture of sand and cow dung.However, in the field the response of E.camaldulensis was only to P and B,showing about a 60% increase in basal area five years after planting.

Eucalyptus tereticornis

Successful fertilizer trials with E.tereticornis have been reported from India (Sinha, 1970; Krishnamurthy and Clement, 1986),Papua New Guinea (Hartley, 1977), Nigeria (Kadeba, 1978), Madagascar (Malvos, 1983) and Brazil (Veiga and Moraes, 1983). Sinha (1970) described the results of three trials laid out in the early 1960's. It was shown that the growth response at one year of E.tereticornis was generally to N and P but in one case also to K when the exchangeable K in the topsoil was considerably lower than in the other case where K was applied.Krishnamurthy and Clement (1986) described an experiment with 4 levels of N, P and K. Significant increases in height at 15 months after planting were obtained with the highest levels of each of N,P and K. Hartley (1977) showed responses to N, P and B for this species on mine tailings up to eight months after application.In Nigeria the response in height growth at one year of age for E.tereticornis was to N and P with a considerably enhanced effect when both nutrients were applied.In Madagascar the response at four years was to P and K with a depressive effect of N but overall best response was obtained by a combined application of NPK. Veiga and Moraes (1983) described the results of different levels of combined NPK applications.The highest level gave a 137% increase in volume production per ha at 10 years after application.

Eucalyptus citriodora

Fertilizer trials with E.citriodora have been carried out in India (Muralidharan and Nair,1973), Nigeria (Kadeba, 1978) and Brazil (Veiga and Moreas, 1983).In India E.citriodora did not respond to applications of N neither in growth nor in yield of leaf or essential oil. Kadeba (1978) quotes that this species trebled its volume per ha four years after aa combined application of N and P.In Brazil E.citriodora increased its standing volume per ha at 10 years from 30 m^3 to about 98 m^3 on average for combined NPK applications or a 227% increase.

Eucalyptus diversicolor

Fertilizer trials with this species have been confined to Western Australia and are restricted to re-establishment trials in the indigeneous Karri forests. Loneragan and Loneragan (1964) showed that E.diversicolor seedlings responded strongly to combined applications of N and P but only slightly to either on their own. They also investigated the so-called "ashbed" effect and it was shown that the major response was due to the supply of P in the ash.Heating the soil per se in the burning process was associated with an overall increase in nutrient supply. Schuster (1979) carried out re-establishment/fertilizer trials in soils damaged by logging. The main treatments were ripping to 1 m,applying bark mulch with some N, and an application of a NP mixture. At 2 years ripping and fertilizing increased height growth individually,but mulching had only an effect when combined with fertilizing or with both other treatments. The same author (1982) undertook further fertilizer trials with E.diversicolor, studying also type, rate, timing and placement of fertilizer. He used various straight and commercial mixtures with N+P, N+P+K and N+P+S as nutrients. At 14 months the best height growth was obtained by the NPK and NPS mixtures. However, the greatest cost efficiency was obtained from a NP application in the form of urea and superphosphate.

Eucalyptus gomphocephala

Most fertilizer trials with this species were carried out in Morocco. An early experiment was described by Marion (1960), laid out in 1951 in which 80 kg N, 24 kg P and 50 kg K was applied per ha. Five years after planting there was still a growth response to these nutrients, that of K being the largest while P gave the lowest mortality.De Beaucorps (1959), obtained also very good results after applying P,K and NPK. Bardhan Roy (1976) also mentioned significant responses to P and K on sandy soils but indicated that in a later experiment E.gomphocephala failed to respond to P but reacted favourably to application of N.

Subgenus Corymbia

Cromer et al (1981) reported that E.nesophila near Darwin in northern Australia still showed a response at 4+ years when N and P were applied together but that the effect was not significant with either nutrient alone.

Subgenus Idiogenes

Early growth responses for E.cloeziana to applications of N,P and K have been found in South Africa (Mhr et al , 1969; Schutz, 1976).At about four years of age the response in height growth was 71% when compared with the unfertilized controls.

Subgenus Monocalyptus

In a NPK and trace element experiment in New South Wales E.pilularis showed a significant response in diameter and height growth to application of NN only,the site being a stabilized dune at low altitude (Cromer et al, 1981). The same authors recorded that E.obliqua in Tasmania also showed a height growth response to N only in the same set of trials.These results were simular for E.sieberi at the same site as for E.pilularis in New South Wales.However,in Gippsland Victoria the height and diameter response of E.sieberi was to P with an additive effect of N which had no effect on its own.

Early NP fertilizer trials with E.regnans in Gippsland , Victoria showed that this species responded to N alone (Cromer, 1971). The same result has been reported from New Zealand where Ballard (1978) pointed out that intensive weed control was required in order to obtain the full benefits. The results for E.fastigata in Gippsland were also the same,responding only to N (Cromer, 1971). However, under different conditions in South Africa the latter species responded appreciably to applications of N, P and dolomitic lime (Schonau, 1983). Early growth responses to N and P were documented also in South Africa for E.dives (Herbert, 1982 a).

Subgenus Symphomyrtus

Initial response to N application was also found for E.deglupta in Papua New Guinea (Lamb, 1977). E.robusta on the other hand showed an initial response to P application in Florida which was maintained until six years of age

(Meskimen and Franklin, 1977). This was also contrary to the results for the first fertilizer trial mentioned above (Dommergues, 1953). However, E.rudis showed the same response up to six years as E.robusta in Florida (Meskimen and Franklin (1977). Similarly, E.dunnii showed also an initial height response to P application in Parana State, Brazil (Lisbao, 1980).

The senior author reported that in a NPK trial with E.bridgesiana on a poorly drained soil in the Transvaal the response up till four years of age was only to N (Schonau, 1983). Likewise, the response at four years of E.nitens in a NPK trial in Victoria,Australia was to N in the form of urea only (McKimm and Flinn (1979). May et al (1975) obtained spectacular responses to low amounts of commercial blended organic fertilizer applied to the same species, resulting in considerable additional timber yields four years after application. Vieira de Brito (1979) showed also considerable additonal timber yields at 11 years for E.globulus ssp maidenii in response to repeated applications of NPK mixtures in Portugal.

As for other species mentioned above, Cromer (1971) found that E.globulus ssp bicostata and E.quadrangulata responded to a single N application shortly after planting in Australia but not to P. In a NPK factorial experiment with E.macarthurii in South Africa Herbert (1987) found that at about two years of age this species responded mainly to a combination of N and P but also to K. On a poorly drained site adjacent to that described above for E.bridgesiana, E.smithii responded differently and up till four years of age the responses to N and P were clearly evident (Schonau, 1983). In a later trial with this species on a well-drained soil the results at 14 months showed that water-soluble P gave slight, although significantly better responses than rock-phosphate (Herbert, 1987).

Cromer (1971) found that E.viminalis like many other species in the same trials responded only to N under the conditions prevailing in Australia. Early growth responses for E.rubida were also reported from lesotho (Richardson, 1981). The fertilization of E.gunnii was studied in France (De Champs, 1983). He tested a range of fertilizer mixtures with water soluble and slow release nutrients. The response in height growth after the second growing season was 15%. It was recommended that only N at a rate of 5 g per tree should be used in commercial practice.

Nutrient deficiencies

Since fertilizer research with eucalypts started on a larger scale in the 1950's many obvious nutrient deficiency symptoms have been noticed, especially when the various species were grown outside their original habitats. On the other hand, these deficiency symptoms have stimulated intensive fertilizer research. Initially the concern was directed to the micro nutrients such as B and Fe, and lately to Cu and Zn. However, more recently deficiencies of the macro nutrients are of great concern which may be aggravated by the latest harvesting techniques and the ever-increasing pressure to shorten rotations. The most important deficiencies will be treated seperately below.

Boron

Ever since Savory (1962) diagnosed a B deficiency in E.alba, E.citriodora, E.grandis, E.saligna, E.torelliana and E.tereticornis in Zambia numerous investigations have been carried out to determine the benefits of B applications. The symptoms of this deficiency resulting in tip die-back, were eliminated by applications of borate in Zambia (Savory, 1962 ; Cooling and Jones, 1970) and Zimbabwe (Steyn and Straker, 1969). It seems that B is mainly important when the climate or soil conditions are marginal for tree growth. The need of various eucalypts for B was confirmed in Nigeria (McComb et al , 1970; Kadeba,1978), Brazil (Knudson et al,1970; Rocha Filho et al , 1979), Papua New Guinea (Hartley,1977 : Lamb 1977), South Africa (Mackenzie and Donald, 1982) and New Zealand (Will, 1985). Cooling (1967) reported an increase of frost resistance in E.grandis through application of B which was not confirmed by McKimm and Flinn (1979) for E.delegatensis and E.nitens in Australia. Rocha Filho et al (1979) studied the deficiency and toxicity symptoms in E.grandis and concluded that the foliar levels of B should be between 46 and 100 mg/kg.

Iron

Severe yellowing or chlorosis of young leaves of E.camaldulensis was first studied in Israel by Karschon (1956). It occurs invariably on calcareous soils containing active lime which induces an Fe deficiency in the leaves. This was also identified for E.dives under waterlogged soil conditions in Australia (Andrew and David, 1959). Ladiges (1977) and Anderson and Ladiges (1978) undertook tests with E.viminalis and E.obliqua respectively using different populations and found that those from acid soils developed severe chlorosis and Fe deficiencies when grown on calcareous soils but those originating from soils with a high pH did not. Application of chelated iron as FeEDDHA to the soil alleviated the chlorosis symptoms (Anderson, 1983) or promoted almost complete recovery (Stewart et al , 1981). In addition to Israel and Australia, Fe dificiency was also reported in New Zealand (Will, 1985) and Brazil (Rocha Filho et al 1978). The latter noted that leaves from the upper parts of E.urophylla should have Fe levels in excess of 140 mg/kg..

Copper and Zinc

Cu and Zn deficiencies in eucalypts and other tree species seem to occur under similar soil conditions, i.e. when the texture is very sandy (Baule and Fricker, 1970; Ballard, 1978; Will 1985; Wallace et al , 1986). These deficiencies occur often simulataneously, the symptoms being weak and pendulous growing tips for Cu and bronze coloured and necrotic leaves for Zn. Apparently the Cu foliar levels should be between 6 and 17 mg/kg (Baule and Fricker, 1970; Schonau, 1984 b) and that for Zn between 10 and 18 mg/kg (Wallace et al 1986; Schonau, 1984 b).It is interesting to note that a probable Cu and Zn deficiency has been identified in E.grandis on the coastal sands in Zululand, South Africa. Mackenzie and Donald (1982) found a response of E.grandis to applications of a mixture of Mg, B and Cu but it is doubtful whether the response is to Cu. On the other hand, Mattos and Maciel (1984) found a severe reduction of foliar Cu levels in E.grandis in Brazil when high P applications were made.

Macro nutrients

From an early stage laboratory studies into deficiencies of N,P,K, Ca and Mg were made in fertilizer research with eucalypts (Will, 1963; Kaul et al 1968; Rocha Filho et al , 1978). The deficiency symptoms described do not always agree and are not very clear for K and Ca. The best descriptions of deficiencies are made for N - greenish yellow, yellowish orange or red foliage depending on species and severity; for P - purple discoloration (Will, 1985); and for Mg - intervenal chlorosis starting from the tips and edges of the leaves (Karschon, 1963). Nowadays, however, concern is expressed for possible future deficiencies of macro-nutrients in countries with old soils which are heavily leached, especially in Brazil (Andrae, 1982; Poggiani et al , 1983; Poggiani 1985).

The trend to whole-tree harvesting, where bark and leaves are removed from the site will lead to a more rapid decrease of the nutrient capital of the ecosystem. Furthermore, a shortening of the rotation will result in relatively more sapwood being removed which has a higher nutrient content than heartwood. (Crane, 1978; Crane and Raison 1983; Ferreira et al, 1984). Crane et al (1981) showed that shortening the rotation for E.delegatensis from 57 to 18 years resulted in a doubling of the P removal from a site. Cromer et al (1983) concluded that harvesting a 9+ year old E.globulus ssp globulus plantation would remove the same amount of P per ha as the original 51 year old E.obliqua natural forest. Likewise burning of trash and litter also depletes the nutrient capital.

Time of application

Fertilizers are usually applied at planting or a few days afterwards. Sinha (1970) reviewing earlier work reported that applications at planting were more advantageous than those after the first weeding. Balloni (1978) confirmed this, citing many relevant investigations and recommending that fertilizer should be applied at planting or soon there-after. Pennefather and MacGillivray (1971) observed a declining response from fertilizer the later it was applied after planting. Hans and Burley (1972) noted that the NPK was applied in their fertilizer trial with E.grandis 2 weeks and 2 months respectively after planting Dicks et al (1965) applied P and K onee week before and N 5+ weeks after planting, and Lckhoff (1955) applied P 4 and 9 months after planting the same species. Krishnamurthy and Clement (1986) divided the fertilizer in three equal portions and applied these one week, and one and two months after planting E.tereticornis . Repeated applications were also indicated by Sinha (1970), Vieira de Brito (1979), Schonau (1983) and Boden (1984). Whether the repeated annual applications as described by Vieira de Brito are beneficial could not be ascertained but this seems doubtful. Contrary to Pennefather and MacGillivray (1971), Cromer (1971) detected no significant growth differences between E.globulus ssp globulus and E.regnans fertilized at planting or two months later. Schuster (1982) studied application timing up to 8 weeks after planting for E.diversicolor and found that the response increased with increasing time between planting and fertilizing up to 4 weeks and that split applications at planting and 4 weeks later were the best treatments.

Method of application

Many different methods of applying fertilizers to various eucalypts have been studied (Brasil Sobrinho et al , 1963; Esparcia, 1973; Hartley,1977; Balloni, 1978; Ballard, 1978; Schuster, 1982; De Champs, 1983; Crane and Raison, 1983; Mattos and Maciel, 1984; Cannon, 1984). Methods tested include applications in the planting hole, in a band, in a furrow, in or along the planting line, in one or more spots, in slots, in a circle or semi-circle, uphill or downhill, broadcast, 15 to 30 cm from the seedling, on or below the surface, covered or uncovered, mixed with the soil or concentrated, in a solution, and as a foliar spray. The results were variable and rather confusing but depended on the type and quantity of fertilizer, texture and nutrient fixing status of the soil and time of application. Thus fertilizers high in N should not be placed in the bottom of the planting hole (Esparcia, 1973; Hartley, 1977), water soluble P fertilizers should not be mixed in P fixing soils (Balloni, 1978; Herbert, 1985 a) and the larger quantities of rock phosphate should be spread over a wide area or broadcast (Rezende et al , 1982).

Type of nutrient and fertilizer

Many different types of fertilizer have been used in experimentation and commercial practice. Initially organic fertilizers were used such as blood and bone (Ballard, 1978) and cow dung (Kadeba, 1978). Mineral fertilizers such as Chilean salpetre (Veiga and Moraes, 1983) and especially various rock phosphates are still widely used depending on availability, price and effectiveness. Similar considerations apply to the sources of Ca and Mg such as calcitic and dolomitic lime. However, the majority of the NPK fertilizers used nowadays are industrially produced mixtures of an inorganic form.

The most frequently used N fertilizers are ammonium sulphate (21%) N with an acid reaction, calcium ammonium nitrate (26% N) being much less acid, and the directly available form at urea (46% N). Moore and Keraitis (1971) investigated the responses of the ammonium and nitrate forms on 12 eucalypts. The differences were not clear but plants of similar ecological habitat tended to give similar responses. P fertilizers are either natural rock phosphates or water-soluble superphosphate in its single, double or triple form. The effectiveness of rock phosphate depends on its total P content and the solubility of the latter in citric acid. This is the mainn reason for different results for E.grandis when comparing the two different sources of P, e.g. Knudson et al (1970) found no differences in response between rock phoshpate and triple superphosphate, Rezende et al (1982) described different results for different types of rock phosphate at different sites, Mattos and Maciel (1984) found that there was no difference in response between a Brazilian rockphosphate and superphosphate, Cannon (1984) described the response to rockphosphate as the least beneficial in Colombia and Herbert (1987) found that height growth was proportional to the amount of superphosphate in mixtures with rockphosphate. K fertilizers are usually in the form of potassium chloride (50% K) or sulphate (40% K) form. In addition to lime, Ca and Mg can be applied in their sulphate form.

Many of the fertilizer experiments are carried out with mixtures such as ammoniated supers, MAP, DAP and other commercial NPK mixtures marketed either in granular form or in tablets. The latter often contain N in a slow-release form such as urea formaldehyde and have not shown great success generally (Herbert, 1985 b) and the use of mixtures in basic fertilized research is questionable. Although the nutrients application rates in fertilizer experiments with eucalypts are generally below 100 kg per ha, the maximum rates amounted to 420 kg N, 191 kg P and 336 kg K per ha (Schonau 1984 a).

Magnitude and maintenance of response

The first report that initial responses to fertilizing eucalypts at planting are maintained was published by Mello et al (1970) in Brazil. This was followed by Schonau and Pennefather (1975) in South Africa and Schonau (1977 a , 1977 b,1983) has stated that this is usually the case if the experiments are designed satisfactorily. Schonau (1984 a) gave 16 references of experiments in which the initial responses were maintained and listed the additional timber yields at harvesting. These additional yields amounted for E.grandis in Brazil to 18,5m˜ per ha at 5 years,in Southern Africa from 25,0 m˜ per ha at 8 years to 98,5 m˜ per ha at 9 years, in the USA to 38,5 m˜ per ha at 9 years; for E.globulus ssp globulus in Australia from 25,8 m˜ per ha at 4 years to 74,7 m˜ per ha at 9,5 years, in Portugal from 64,0 to 80,2 m˜ per ha at 12 years;for E.globulus ssp maidenii in Portugal to 47,8 m˜ per ha at 11 years, and for E.nitens in Australia to 38,3 m˜ per ha at 4 years. Supplementary information on additional timber yields have been obtained from Spain for E.globulus ssp globulus which amounted to 29 m˜ per ha at 5 years (Temes and Santiago, 1977) and from Brazil amounting to 76 m˜ per ha for E.tereticornis and 68 m˜ per ha for E.citriodora, both at 10 years of age (Veiga and Moraes, 1983). There was only one experiment with E.grandis of which it was reported that the initial response to fertilizing at planting was not maintained (Daniels, 1974; Donald and Schutz, 1977). This result was ascribed to application of the P fertilizer and mixing it with soil before planting, poor weed control, incorrect and low application, high stocking and an inefficient experimental design (Schonau, 1983).

Economics of fertilizer application

The economic justification of applying fertilizer to eucalypts at planting is often ascribed to additional benefits such as shortening the rotation and earlier canopy closure and subsequently reduced weed control (Schutz, 1976). In addition it may be economically warranted when eucalypts are grown underr marginal conditions where acute nutrient shortages occur. However, the true criterion is whether the additional investment of fertilizing earns a profit in real terms at harvesting including compound interest at present-day replacement costs and ruling timber prices. Profitability of fertilizing eucalypts has been indicated by Knudson et al (1970), Mello et al (1970), May et al (1975) , Schonau and Pennefather (1975), Schonau (1977 b , 1983) and Herbert (1983). The real internal rate of return on fertilizing costs varied between 15,4 and 41,0% per annum. More recently De Champs (1983) calculated that fertilizing E.gunnii in France cost only about US $11 per ha, a small amount when compared with total establishment costs. Cannon (1984) stated that the costs of the optimum fertilizer application in Colombia amounted to no more than 3% of current plantations costs, including landprice and establishment costs. Boden and Herbert (1986) made a detailed study of the interaction between establishment method and fertilizing E.grandis . In all cases fertilization with the relevant fertilizer improved the results for the various methods of establishment and they stated that the real internal rate of return for fertilizing on its own amounted to approximately 25%.

THE ROLE OF FERTILIZERS

The main factors affecting stand development of eucalypt plantations are soil water, nutrients, organic matter, effective rooting depth and friability, as well as quality of seed and nursery stock, site preparation and weed control. Of these the first two could be considered the most important and are inversely related. For example, if the effective rainfall is high in warm temperate and sub-tropical areas suitable for eucalypts, soil water and consequently weathering and leaching is high and nutrient content of the soil low and vice versa .Thus, if the climate of a certain area is suitable for a specific eucalypt species, there is usually a need for fertilizing. The main objectives of the latter for eucalypts are to rectify nutrient deficiencies, to build up nutrient capital and to increase merchantable produce. Building up of nutrient capital is of particular importance for eucalypts since they are grown to a large extent in plantation form on land which has never been afforested before, has carried an open forest vegetation (Savannah) or has been cleared of forests for a long time.

Functions of N,P and K

The functions of the main nutrients are described in standard references and emphasized for tree species by Baule and Fricker (1970). Basically, N is one of the fundamental units in proteins and chorophyll, it controls the formation of foliage determining the amount of plant production and consequently that of wood increment. P is also important in plant metabolism and its highest concentration occurs in parts that are growing rapidly and is of prime importance for root development. K is not a constituent of organic compounds and its primary role is as an enzyme activator. It is indispensable in the synthesis of proteins and carbohydrates and the translocation of the latter. In addition it plays an important part in stomatal action and has been found to be important under lower rainfall conditions.

Fertilizer, site and species interactions

At first glance, the responses to fertilizer applications to eucalypts seem rather confusing. However, study of the experimental evidence reveals that except in cases of acute deficiencies, the responses are mainly to N and P, the requirements for each of these nutrients depending on the availability of the other on a given site and on their supply being well balanced. Thus, N is the major nutrient required on alluvial soils, recent sands, volcanic soils and other relatively young soils low in organic matter. On the other hand, P is in greater demand on older more leached soils where a certain degree of organic matter accumulation has taken place, such as occur frequently in Brazil, southern Africa, Australia and the southern USA.

Considering the main functions of N and P in the growth of eucalypts, applications of P are needed in the early stages of tree development and should be given at planting when it's supply is limited. In order that P is available as soon as possible, the more water soluble superphosphate fertilizer is usually preferred to rock phosphate. Applications of N could follow later but the balance between N and P should always be borne in mind carefully as has been indicated by the many authors mentioned above for E.grandis . In consequence, different site conditions and site preparation techniques require different fertilizer mixtures as is apparent from the recommendations given for E.grandis in South Africa (Schonau and Boden, 1982; Schonau, 1983 and 1984 b ; Herbert 1985 a and 1988).

Although less frequently reported, similar fertilizer/site interactions seem to exist for K. Responses to applications of this nutrient have been described for E.grandis (Heibert-Iurgensen and Pennefather, 1966; Mello 1968; Pennefather and MacGillivray, 1971; Herbert 1983), and for E.camaldulensis, E.cloeziana, E.diversicolor, E.gomphocephala and E.macarthurii by Malvos (1983), Mhr et al (1969), Schuster (1982), Marion (1960) and Herbert (1987) respectively. The reasons for the lack of response to K are not clear but recorded responses to this nutrient appear to occur mainly on soils derived from rocks inherently low in K and when the effective rainfall is marginal. However, application of K is frequently recommended in conjunction with N and P in order to prevent possible imbalances caused by this nutrient.

Similarly, species/site interaction in fertilizer response are apparent for acute deficiencies of micro-nutients. For example, B dificiencies seem to occur mostly on acid granite-derived soils, on volcanic soils, and especially where conditions are droughty. Fe deficiencies develop invariably on calcareous soils containing active lime, while Cu and Zn deficiencies have been reported only on podzolic soils with a very sandy nature.

Compared to conifers, differential growth response of various clones or families of eucalypts to fertilizer application has been little investigated. Meskimen (1971) found consistent growth responses for three families of E.camaldulensis .This was confirmed by Balloni (1978), Lisbao (1980) and Cromer et al (1981) for other eucalypts. The last mentioned authors, working with various species, stated that the nature of the response was determined by site factors rather than species. Only Meskimen and Franklin (1977) showed different growth responses for E.camaldulensis ascribed to a "phosphate degrade" and stunted growth on one particular site.

MONITORING OF FERTILIZER RESPONSES

In 1976 Schutz still hesitated to accept universally sustained growth responses of short rotation eucalypts to fertilizer application. The overwhelming evidence which has come to light since then puts this issue beyond doubt. These sustained growth responses may be caused by the improved root system, improved internal nutrient status of the tree and early canopy closure, and limiting weed competition which in turn increases water and nutrient availability for the trees. It has been shown that the absolute response is greatest on the best sites but that the percentage increase is the greatest on poor sites (Schonau, 1984 a ;Herbert, 1985 a). The latter is of appreciable importance since it can make man-made forests on marginal sites profitable.

From frequently enumerated experiments, it has been shown that the height and diameter response becomes apparent at an early stage and that the absolute differences in these parameters are maintained until harvesting Schonau, 1977 a ; Cromer and Williams, 1982; Herbert et al 1982; Herbert, 1983; Schonau, 1984 b).The same authors pointed out that as a consequence the responses of basal area and ipso facto that of volume per ha will show an increase for at least ten years unless the response differences are overshadowed by site differences within the experiments. In addition Herbert (1982 b) showed that form factor is strongly influenced by fertilizer treatments and that volume estimates based only on tree diameter and height may underestimate the response to fertilizing eucalypts.

Another prerequisite for maintenance of responses to fertilizing eucalypts with N and P is that the proportions of these nutrients are finely balanced. This can be monitored from the ratio of the foliar concentrations of these nutrients as shown by Cromer et al (1981), Schonau (1981, 1982) and Schonauu and Herbert (1982, 1983). It is interesting to note that Cromer sets the foliar N/P ratio for E.grandis at less than 15, while the latter authors state 13 and Lamb (1977) refers to a ratio of 11,9 for E.grandis seedlings. There is also close agreement between the optimum foliar level of N on its own set by the authors (>2%) and 2,22% mentioned by Barros and Pritchett (1979).

Foliar analysis is the most accurate method of diagnosing nutrient deficiencies (Ballard, 1978). Alternatively, Herbert (1988) showed that response surfaces with basal area per ha at four years of age as dependent and fertilizer applications as predictor variables are useful for treatment evaluation within and between experiments. Another method is the regression of mean height or monthly height growth on foliar levels and fertilizer application. Lamb (1977) obtained good results for 2 experiments with E.deglupta explaining 72% of the height growth at 15 months from the foliar N and P levels. Schonau and Herbert (1982) achieved similar results for three experiments, the coefficient of determination being between 42 and 74% for each experiment separately and 59% for all three combined, with monthly height growth as dependent and foliar N,P and K ratios and level of P application as predictor variables. When the data base was extended to all macro- and micro nutrients levels, the ratios of the former, and N and P application rates, the R) became 72% for the same three experiments (Schonau and Herbert, 1983).

RECOMMENDATIONS

Tree growth is a function of climate, soil, genetic potential and silvicultural practices. For any species, the main recourse open to silviculturists for increasing yields is to exploit the full site potential by improving soil conditions, particularly at time of planting. The concept behind fertilizing at planting relies on providing a sufficiency of suitable nutrients for the unimpeded and rapid establishment of roots. For this reason, applications are made on an individual tree basis rather than trying to improve the fertility of the site as a whole. Similarly, water-soluble fertilizers being readily available, are generally most suitable.

Fertilizing should aim to ensure sufficient readily available P for rapid root development, while maintaining optimum ratios with other elements, especially N and K. On fully cultivated sites, the choice of fertilizer may best be judged from the depth and organic matter content of the topsoil, the degree of weathering of the soil, the parent material from which the soil is derived and the effective rainfall. Soils high in organic matter require approximately 10 g P per tree in a fertilizer with a low N : P ratio (viz 1 : 3), as such soils contain considerable mineralizable N. Where complete cultivation has not been carried out prior to planting, the fertilzer N : P ratio should be increased due to lower rates of N mineralization. Conversely eucalypts planted on soils low in organic matter will respond best to N on its own (10-20 g N/tree) or a fertilizer with a high N : P ratio (viz 2 : 1). Soils derived from geological formations low in K bearing minerals, or soils in drier areas may also require K in addition to N and P. For these, the K : P ratio should generally not exceed one.

As fertilizing at planting stimulates the development of an intensive and extensive root system, fertilizers are best applied at or soon after planting. This stimulation is both direct at the zone of contact with the root for P fertilizers, and indirect through the development of a vigorous crown supplying photosynthate to the roots. Accordingly fertilizers should be placed so as to intercept as many roots as possible while at the same time minimizing root scorch and particularly P- fixation by the soil. Thus it should not be mixed into the soil but banded in a ring with a radius of 15 - 20 cm around the seedling or in two broad slots on either side. For fertilizers high in N this distance should be increased to 30 cm. The depth of placement should be similar to that of the root plug (q 10 cm below the surface) this being the zone of maximum root activity. This helps prevent problems with fertilizer dispersion by wind and rain, as well as enhancing the solubility of the fertilizer through restricting drying out at the surface.

The benefits of fertilizing are many. It allows the seedling to take full advantage of the effects of cultivation on soil aeration, friability and water infiltration and storage. These conditions in turn promote the efficient uptake of nutrients and therefore the response to fertilizing. The net result is rapid colonization of the soil by roots, early and full utilization of the site, a permanently improved root system and internal nutrient status, better survival, rapid canopy closure and weed suppression, a more uniform stand, compaction of the establishment period and greater yields at clearfelling. It is important to note the effect of fertilizing on root formation and structure, as this is the main reason for the response to fertilizing increasing with time. A well developed root system is able to fully exploit the resources a site has to offer, as well as to maximize the interception of soil water moving through the profile. Thus the absolute response is highest on good sites but relatively greatest on poor sites. Furthermore, as soil water availability is often the main factor limiting tree growth, the magnitude of the response for a given site is proportional to the water balance during the rotation.

Fertilizing has been shown to be the single most profitable component of the establishment operation. Improvements in yields at clearfelling range from 20 to 40 percent on an eight to ten year rotation. However, it must be stressed that fertilizing is only part of an integrated approach to establishing trees with vigorous and well developed root systems. Thus best results are obtained on fully cultivated sites and using sound nursery stock where root deformation, strangulation and senescence have been avoided. Similarly, thorough weed control is essential,as weeds respond very rapidly to fertilizers, thereby reducing its availability to the tree and increasing competition for light and soil water. The profitability of fertilizing can only be maximized where all aspects of establishment are complementary and properly carried out.

Under new afforestation conditions, the correct choice of fertilizer type and rate can be inferred by examining the soil. This may be improved upon by examination of the foliar nutrient levels from initial plantings to check the order of importance of macro elements and their relationship to one another, as well as the possibility of micro-nutrient deficiencies. However, it will still be necessary to lay out fertilizer trials on the range of sites encountered, selecting treatments and levels within treatments from those recommended earlier in this section.

Much confusion has arisen in the past from poor experimental techniques in fertilizer research. Trials should be adequately replicated in time and space, and laid out systematically with early results being implemented in later experiments. Factorial designs are invariably the most suitable. The selection of only a few fertilizer combinations in randomized blocks does not allow for the computation of response surfaces. Properly replicated factorial designs also have a high degree of control on the error term, especially when confounding is made use of.

Sites for fertilizer trials should be as uniform as possible as regards soils, aspect, drainage and vegetation cover. For this reason, as complete a method of site preparation as possible should be employed. Similarly, planting stock should be of high quality and carefully planted. The actual planting also requires a high level of supervision. It is not unknown for treatments to be applied to the wrong plots, or the same care with which seedlings were planted at the start of the day to be lacking in the afternoon. The experiments should also be managed with a view to controlling variation - a major cause of failure in field trials. Thus optimum site preparation and silviculture should be employed, in order to improve uniformity and maximize true treatment response, and the view that commercial afforestation conditions should be retained is mistaken. Blanking should be done as early as possible and weeds kept fully controlled. Variation on the site can also be controlled by judicious placement of replications and blocks within replications. This factor has been neglected in many past trials, and is largely responsible for the early advantages enjoyed by some treatments being reduced as trees begin to grow at a limited rate increasingly imposed by their individual micro-sites. Trials must also be managed with regard to the frequency of measurement and the choice of parameter to be monitored. Diameter and height measurements should overlap at least once as height measurements give way to those of diameter, since these parameters tend to show differences in their response. Foliar sampless should also be taken, not only to study the nature of the response, but also to provide information on fertilizer recommendations for trees growing sub-optimally.

REFERENCES

ANDERSON, C A, 1983 : The effect of FeEDDHA on the development of lime-chlorosis in two seedling populations of Eucalypts obliqua L'Hrit. Plant and Soil (70) : 299-302.

ANDERSON, C A, & LADIGES, P Y, 1978 : A comparison of three populations of Eucalyptus obliqua L'Hrit growing on acid and calcareous soils in southern Victoria. Aust J Bot (26) : 93-109.

ANDRAE, F, 1982 : Zweitintentur eines Eucalyptus saligna Bestandes in Sdbrasilien. Centralblatt fr das gesamte Forstwesen (99) : 193-217.

ANDREW, W D & DAVID, D J, 1959 : Iron deficiency in Eucalyptus dives Schauer. Proc Linn Soc NSW (84) : 256-258.

BALLARD, R, 1978 : Use of fertilizers at establishment of exotic plantations in New Zealand. New Zealand J For Sci (8) : 70-104.

BALLONI, E A, 1978 : Fertilizacao florestal. Bol Inf IPEF (6) 16 : A 1-34.

BARDHAN ROY, B K, 1976 : Experiences of fertilizer-treatment in Eucalypts - A discussion. Indian Forester (102) : 168-173.

BARROS, N F & PRICHETT, W L, 1979 : Effect of sources and rates of nitrogen on growth and composition of Eucalyptus grandis. Soil Crop Sci Soc Fla Proc (38) : 101-104.

BAULE, H & FRICKER, C, 1970 : The fertilizer treatment of forest trees. BLV, Mchen, 259 pp.

BODEN, D I, 1984 : Early responses to different methods of site preparation for three commercial tree species. Proc IUFRO Symp Site and Productivity of Fast growing Plantations , Pretoria and Pietermaritzburg (2) : 565-578.

BODEN, D I & HERBERT, M A, 1986 : Site preparation of Eucalyptus grandis at Glendale, Natal Midlands : provisional estimates of profitibality. Inst

Commer For Res Annual Report , 1986 : 119-122.
BOWMAN, D M & KIRKPATRICK, J B, 1986 : Establishment, suppression and growth of Eucalyptus delegatensis R T Baker in multiaged forests III. Intraspecific Allelopathy, competition between adult and juvenile for moisture and nutrients, and frost damage to seedlings. Aust J Bot (34) : 81-94.
BRASIL SOBRINHO, M O C do, MELLO, F A F de, RODRIGUES, N & MELLO, H A,1963: A comparison of various methods of fertilizer placement in the planting of eucalyptus. Fertilit (18) : 15-21.
CAMERON, D M, RANCE, S J & WILLIAMS, E R, 1983 : Nutrition studies with irrigated Eucalyptus camaldulensis in northern Australia.Silvicultura (32) : 669-670.
CANNON, P G, 1984 : Fertilization of Eucalypt seedlings in some andept soils of Colombia. Proc Int Conf Volcanic Soils , Cape Verde Islands : 237-247.
COOLING, E N, 1967 : Frost resistance in Eucalyptus grandis following the application of fertilizer borate. Rhod Zamb mal J Agric Res (5) : 97-100.
COOLING, E N & JONES, B E, 1970 : The importance of boron and NPK fertilizers to Eucalyptus in the southern province, Zambia.E Afr Agric For J (36) : 185-194.
CRANE, W J B, 1978 : Phosphorus stability in eucalypt forests. Aust For J (41) : 118-126.
CRANE, W J B & RAISON, R J, 1983 : The nutritional effect of short rotation silviculture. Silvicultura (32) : 670-672.
CRANE, W J B, RAISON, R J, NICHOLLS, G H & GODKIN, C M, 1981 : The effect of rotationial age on the phosphorus requirements of forest plantations. Proc Austr For Nutr Workshop , Canberra : 325.
CROMER, R N, 1971 : Fertilizer trials in young plantations of eucalypts. Aust For Res (5) : 1-10.
CROMER, R N, 1984 : The influence of nutrition on growth and photosynthesis in Eucalyptus.Proc IUFRO Symp Site and Productivity of Fast-growing Plantations , Pretoria and Pietermaritzburg (2) : 669-678.
CROMER, R N, CAMERON, D,CAMERON, J N, FLINN, D W, NEILSEN, W A, RAUPACH, M, SNOWDON, P & WARING, H D, 1981 : Response of eucalypt species to fertilizer applied soon after planting at several sites.Aust For (44) : 3-13.
CROMER, R N, RAUPACH, M, CLARKE, A R P & CAMERON, J N, 1975 : Eucalypt plantations in Australia - the potential for intensive production and utilization. Appita (29) 165-173.
CROMER, R N & WILLIAMS, E R, 1982 : Biomass and nutrient accumulation in a planted E.globulus (Labill) fertilizer trial. Aust J Bot (30) : 265-278.
CROMER, R M, WILLIAMS, E & TOMPKINS, D, 1983 : Biomass and nutrient uptake in fertilized E.globulus. Silvicultura (32) : 672-674.
DANIELS, F W, 1974 : Report on the Eucalyptus grandis fertilizer trial at Louw's Creek. Unpubl Rep S Afr Dep For, 12 pp.
DE BEAUCORPS, G, 1959 : Rapports entre les peuplements d'eucalyptus et les sols sableux de la Mamora et du Rharb. Ann Rech For Moroc (5) : 216.
DE CHAMPS, J,1983: La fertilisation de l'Eucalyptus gunnii au moment de la

plantation. Proc Colloq Intern sur les Eucalyptus au Froid , Bordeaux : 292-299.

DICKS, H M, JACKSON, D A & KIRK, R D, 1965 : Fertilization of Eucalyptus grandis/saligna - a preliminary report. S Afr For J (54) : 22-29.

DOMMERGUES, Y, 1953 : Influence de la fumure des plants "d'Eucalyptus robusta "sur la croissance de cette essence et sur l'activit biologique du sol. Mm Inst Sci Madagascar D (5) : 315-325.

DONALD, D G M & SCHUTZ, C J, 1977 : The response of Eucalyptus to fertilizer application at planting : the Louw's Creek trial. S Afr For J (102) : 23-28.

ELLIS, R C, WEBB, D P, GRALEY, A M & ROUT, A F, 1985 : The effects of weed competition and nitrogen nutrition on the growth of seedlings of Eucalyptus delegatensis in a highland area of Tasmania, Aust For Res (15) : 395-408.

ESPARCIA, E G, 1973 : Effect of placement of phosphatic fertilizers on Eucalyptus growth. FAO/IUFRO Symp For Fert, Paris.

ESPARCIA, E G, 1983 : Mineral contents of Eucalyptus globulus, Pinus and Quercus suber and the aluminium biociclage of these species in the same conditions of soil and mediterranean climate. Silvicultura (32) : 675-678.

FERREIRA, M d G M, KIMMINS, J P & BARROS, N M, 1984 : Impact of intensive management on phosphorus cycling in Eucalyptus grandis plantations in the Savannah region. Minas Gerais, Brazil. Proc IUFRO Symp Site and productivity of Fast-growing Plantations, Pretoria and Pietermaritzburg (2) : 847-856.

FLINN, D W, 1976 : Nutrition of Eucalyptus globulus at Powelltown. For Tech Pap Victoria (25) : 5-7.

HANS, A S & BURLEY, J 1972 : Wood quality of Eucalyptus grandis (Hill) Maiden in a fertilizer trial at Siamambo, Zambia. E Afr Agric For J (38) : 157-161.

HARTLEY, A, 1977 : The establishment of Eucalyptus tereticornis on tailings from the Bougainville copper mine, Papua New Guinea. Commonw For Rev (56) : 239-245.

HEIBERG-IURGENSEN, K & PENNEFATHER, M, 1966 : Fertilizing of Eucalyptus grandis (saligna) on old wattle lands. S Afr For J (57) : 11-12.

HERBERT, M A, 1982 a : Fertilizing of Eucalyptus dives. Annual Rep Wattle Res Inst For 1981-1982 : 67-68.

HERBERT, M A, 1982 b : Comparisons between different mensurational techniques and their analyses for a factorial fertilizer experiment with Eucalyptus grandis. Proc Jubilee Symp Univ Stellenbosch (1) : 207-220.

HERBERT, M A, 1983 :The response of Eucalyptus grandis to fertilizing with nitrogen, phosphorus, potassium and dolomitic lime on a Mispah soil series. S Afr For J (124) : 4-12.

HERBERT, M A, 1985 a : Fertilizing at Planting.Inst Commer For Res Annual Rep, 1985 : 125-129.

HERBERT, M A, 1985 b : Fertilizing Eucalyptus grandis.Inst Commer For Res Annual Report , 1985 : 58.

HERBERT, M A, 1987 : Fertilizing E.grandis and E.smithii and E.macarthurii . Inst Commer For Res Annual Report , 1987 : 19-20.

HERBERT, M A, 1988 : Fertilizer and site interactions on the growth and foliar nutrient levels of Eucalyptus grandis. For Ecol Manage (in press).
HERBERT, M A, , JACKSON, D A & VERLOREN VAN THEMAAT, R, 1982 : Final findings on the response of Eucalyptus grandis to fertilizing at De Kaap, Eastern Transvaal. S Afr For J (122) : 53-58.
KADEBA, O, 1978 : Nutritional aspects of afforestation with exotic tree species in the Savannah region of Nigeria. Commonw For Rev (57) : 191-199.
KARSCHON, R, 1956 : Iron chlorosis of Eucalyptus camaldulensis Dehn and its incidence in relation to soil conditions. Repr Ilanoth (3) : 7-35.
KARSCHON, R, 1963 : A probable cause of magnesium deficiency in Eucalyptus gomphocephala A DC. Israel J Agric Res (13) : 173-175.
KAUL, O N, SRIVASTAVA, P B L & TANDON, V N, 1968 : Nutrition studies on Eucalyptus III Diagnosis of mineral deficiencies in Eucalyptus grandis seedlings. Indian For (94) : 831-834.
KNUDSON, D, YAHNER, J E & CORRUEA, H, 1970 : Fertilizing eucalypts on Brazilian savanna soils. Commonw For Rev (49) : 30-40.
KRISHNAMURTHY, R & CLEMENT, V, 1986 : Response of Eucalyptus "Hybrid" (Mysore gum) to major nutrient elements. Eucalyptus in India. Past present and future : 126-131.
LADIGES, P Y, 1977 : Differential susceptibility of two populations of Eucalyptus viminalis Labill to iron chlorosis. Plant and Soil (48) : 581-597.
LAMB, D, 1977 : Relationship between growth and foliar nutrient concentrations in Eucalyptus deglupta. Plant and Soil (47) : 495-508.
LEPOUTRE, B & MANDOURI, T, 1976 : Resultats des essais preliminaires de fumure minrale sur Pinus pinaster et Eucalyptus camaldulensis en Mamora. Ann Rech For Moroc (16) : 65-99.
LISBAO, L, 1980 : Frost effect and the initial behaviour of three Eucalyptus dunnii Maiden provenances in a combined spacing and fertilizer trial. Bol Pesq Flor, URPFCS (1) : 28-49.
LONERAGAN, O W & LONERAGAN, J F, 1964 : Ashbed and nutrients in the growth of seedlings of Karri (Eucalyptus diversicolor Fv M).J Roy Soc W Aust (47) : 75-80.
LCKHOFF, H A, 1955 : The establishment and regeneration of Eucalyptus saligna plantations in the coastal belt of Zululand. J S Afr For Ass (25) : 1-20.
MACKENZIE, A A & DONALD D G M, 1982 : Weed control and fertilizer use in South African forest establishment. Proc Jubilee Symp Univ Stellenbosch (1) : 295-304.
MALVOS, C, 1983 : First results on fertilization trials given to Eucalyptus plantations in Madagascar. Silvicultura (32) : 625-626.
MARION, J, 1960 : Un exemple de reprise assure par l'emploi des engrais sur une plantation d' Eucalyptus. Rev For Fr (12) : 26-34.
MATTOS, C M & MACIEL, R, 1984 : Competition between natural phosphate and simple superphosphate. Proc IUFRO Symp Site and Productivity of Fast-growing Plantations , Pretoria and Pietermaritzburg (2) : 679-689.
MAY, F J, PEDERICK, L A & CRAIG, F G, 1975 : Fertilizer responses in Eucalyptus nitens at Powelltown. For Tech Pap Victoria (22): 11-14.

McCOMB, A L, OJO, G O A & JACKSON, J K, 1970 : Fertilizer response of Eucalyptus grandis in a basaltic soil from the Mambilla Plateau,Nigeria Savanna For Res Stn, Nigeria Res Leaflet (2), 7 pp.
McINTYRE, D K & PRYOR, L D, 1974 : Response of flooded gum in plantations to fertilizers. Aust For (37) : 15-23.
McKIMM, R J & FLINN, D W, 1979 : Eucalypt species, site preparation and fertilizer requirements for reforestation of the Toorongo Plateau in central Victoria. Aust For (42) : 117-124.
MELLO, H A,1968 : Aspectos do emprgo de fertilizantes minerais no reflorestamento de solos de cerrado do estado de Sao Paulo, com Eucalyptus saligna Sm. Unpubl Thesis Univ Sao Paulo, 176 pp.
MELLO, H A, MASCARENHAS SOBRINHO, J, SIMOES, J W & do COUTO, H T Z, 1970 : Resultados da aplicacao de fertilizantes minerais na producao de madeira de Eucalyptus saligna Sm em solos de cerrado do estado de S Paulo.IPEF Publ Semestral (1) : 7-26.
MESKIMEN, G, 1971 : Fertilizer tablets stimulate Eucalyptus in Florida trial. USDA For Serv Res Note SE-162, 8 pp.
MESKIMEN, G F & FRANKLIN, E C, 1977 : Performance of eucalypts with phosphate on southwest Florida sites. Unpubl manuscript, 11 pp.
MHR , P J, KIRK, R D, MULLINS, A J, COLE, J A & DICKS, H M, 1968 : Unpubl Research Report IV - timber trials 1966/67. Fisons Mark Dep.
MHR, P J, KIRK, R D, MULLINS, A J, COLE, J A & RANWELL, J F, 1969 : Unpubl Research Report XI - timber trials 1968-1969. Fisons Mark Dep.
MOORE, C W E & KERAITIS, K, 1971 : Effect of nitrogen source on growth of Eucalyptus in sand culture. Aust J Bot (19) : 125-141.
MURALIDHARAN, A & NAIR, E V G, 1973 : Response of Eucalyptus citriodora Hook to different levels of nitrogen and pruning. Indian J Agric Sci (43) : 868-871.
PENNEFATHER, M & MACGILLIVRAY, F, 1971 : Fertilizing of Eucalyptus grandis (Saligna) on old wattle soils, S Afr For J (76) : 1-5.
POGGIANI, F, 1985 : Nutrient Cycling in Eucalyptus and Pinus plantation ecosystems. Silvicultural implications.IPEF, Piracicaba (31) : 33-40.
POGGIANI, F, COUTO, H T Z do, SUITER FILHO, W, 1983 : Biomass and nutrient estimates removed in short rotation intensively cultured plantations of Eucalyptus grandis. Silvicultura (32) : 648-651.
RANDWELL, J F, 1975 :Response of Eucalyptus grandis and Eucalyptus saligna to fertilization. Fert Soc S Afr J (1) : 45-46.
RANDWELL, J F, KIRK, R D & MULLINS, A J, 1974 : A preliminary study on the response of timber in the Transkei to fertilization. Fert Soc S Afr J (1) : 9-14.
REZENDE, G C de, BARROS, N F de, ALMEIDA MORAES, T S de, MENDES, C J & SUITER FILHO, W, 1982 : Aplicacao de fosfatos naturais em plantios de Eucalyptus grandis W Hill ex Maiden. Revista Arvore (6) : 74-83.
RICHARDSON, K F, 1981 : Unpubl reports on fertilizer trials in E.rubida for Lesotho Woodlot Project.
ROCHA FILHO, J V de C, HAAG, H P & OLIVEIRA, G D de, 1978 : Deficincia de macronutrientes, boro e ferro em Eucalyptus urophylla.Anais da Escola Superior de Agricultura "Luiz de Queiroz" (35) : 19-34.
ROCHA FILHO, J V de, HAAG, H P, OLIVEIRA, G D de & SARRUGE, J R, 1979 : Influnca do boro no crescimento e na composicao quimica do Eucalyptus

grandis. Brasil florestal (9, 39) : 29-33.
SAVORY, B M, 1962 : Boron deficiency in eucalypts in Northern Rhodesia Emp For Rev (41) : 118-126.
SCHONAU, A P G, 1977 a:Initial responses to fertilizing Eucalyptus grandis at planting are sustained until harvesting. S Afr For J (100) : 72-80.
SCHONAU, A P G, 1977 b :Some controversial issues in silviculture. S Afr For J (100) : 27-31.
SCHONAU, A P G, 1981 : The effects of fertilizing on the foliar nutrients concentrations in Eucalyptus grandis. Fertilizer Res (2) : 73-87.
SCHONAU, A P G, 1982 : Additional effects of fertilizing on several foliar nutrient concentrations and ratios in Eucalyptus grandis. Fertilizer Res (3) : 385-397.
SCHONAU, A P G, 1983 : Fertilization in South African Forestry. S Afr For J (125) : 1-19.

SCHONAU, A P G, 1984 a :Fertilization of fast-growing broadleaved species. Proc IUFRO Symp Site and Productivity of Fast-growing Plantations , Pretoria and Pietermaritzburg (1) : 253-268.
SCHONAU, A P G, 1984 b : Silvicultural considerations for high productivity of Eucalyptus grandis. For Ecol Manage (9) 295-314.
SCHONAU, A P G & BODEN, D I, 1982 : Silvicultural techniques in the establishment of Eucalyptus grandis. Proc Jubilee Symp Univ Stellenbosch (1) : 269-294.
SCHONAU, A P G & HERBERT, M A, 1982 : Relationship between growth rate and foliar concentrations of nitrogen, phosphorus and potassium for Eucalyptus grandis . IUFRO XVII World Congress, Kyoto, Japan (1981).S Afr For J (120) : 19-23.
SCHONAU, A P G & HERBERT, M A, 1983 : Relationship between growth rate, fertilizing and foliar nutrient concentrations for Eucalyptus grandis. Fertilizer Res (4) : 369-380.
SCHONAU, A P G & PENNEFATHER, M, 1975 : A first account of profits at harvesting as a result of fertilizing Eucalyptus grandis attime of planting in Southern Africa. S Afr For J (94) : 29-35.
SCHONAU, A P G, VERLOREN VAN THEMAAT, R & BODEN, D I, 1981 : The importance of complete site preparation and fertilizing in the establishment of Eucalyptus grandis. S Afr For J (116) : 1-10.
SCHUSTER, C J, 1979 : Rehabilitation of soils damaged by logging in south-west Western Australia. Res Pap For Dep W Aust (54) : 8 pp.
SCHUSTER, C J, 1982 : Fertilizing planted Karri (Eucalyptus diversicolor F Muell) seedlings. Res Pap For Dep W Aust (70) : 11 pp.
SCHUTZ, C J, 1976 : A review of fertilizer research on some of the more important conifers and eucalypts planted in subtropical and tropical countries, with special reference to South Africa. Bull 53, Dep For, Pretoria, 89 pp.
SIMOES, J W, MELLO, H A, LEITE, N B & CIERO NETTO, A, 1972 : Resultados preliminares sobre a fertilizacao fosfatada no plantio de eucalipto (nota prvia). IPEF Publ Semestral (5) : 62-64.
SINHA, B N, 1970 : Use of fertilizers in Eucalyptus plantations. Indian For (96) : 755-765.

STEWART, H T L, FLINN, D W, BALDWIN, P J & JAMES, J M, 1981 : Diagnosis and correction of iron deficiency in planted eucalypts in north-west Victoria. Aust For Res (11) : 185-190.
STEYN, J J & STRAKER, M F B, 1969 : The application of boron to gum trees. Rhodesian Agric J (66) : 148.
TEMES, S B & SANTIAGO, F M, 1977 : Suministro lento de nutrientes con fertilizantes pastillados paro uso forestal. Estudio lisimetrico de las pastillas y resultados de las experiencias de fertilizacion. An INIA / Ser Recursos Naturales (3) : 235-249.
VEIGA, A A & MORAES, J L de, 1983 : Fertilizacao mineral em Pinus e Eucalyptus. Silvicultura (32) : 630-632.
VIERA de BRITO, F M, 1979 : Response of Eucalyptus to fertilization.Unpubl manuscript Centro de Desenvolvimento Agricola, 9 pp.
WALLACE, I M, DELL, B & LONERAGAN, J F, 1986 : Zinc nutrition of Jarrah (Eucalyptus marginata Donn ex Smith) seedlings. Aust J Bot (34) : 41-51.
WARD, S C, PICKERSGILL, G E, MICHAELSON, D V & BELL, D T, 1985 : Responses to factorial combinations of nitrogen, phosphorus and potassium fertilizers by saplings of Eucalyptus saligna Sm,and the prediction of the responses by DRIS indices. Aust For Res (15) : 27-32.
WILL, G M, 1963 : Some changes in the growth habit of Eucalyptus seedlings caused by nutrient deficiencies. Fertilit (19) : 3-12.
WILL, G M, 1985 : Nutrient deficiencies and fertilizer use in New Zealand exotic forests. For Res Bull New Zealand For Serv : 53 pp.

XI

EFECTO DE LA FERTILIZACION EN EL DESARROLLO INICIAL DE PLANTACIONES DE EUCALYPTUS

Jorge Toro Vergara (*)

RESUMEN

La fertilización en plantaciones de Eucalyptus recién establecidas, es una línea de trabajo que ha empezado recientemente en Chile y que ha mostrado ser muy promisoria.

Parte de las experiencias que se comentan en este trabajo se han efectuado entre la VI y VIII Región, cubriendo suelos agrícolas agotados y suelos forestales de alta productividad.

La fertilización da buenos resultados cuando se le utiliza sola, pero a veces es necesario combinarla con el control de malezas o con la remoción de suelo, o en casos extremos emplear las tres técnicas en conjunto.

Dependiendo de las características del sitio es el tipo de actividades a desarrollar.

El análisis de suelo es una ayuda eficaz para detectar algún factor adverso de tipo físico y para conocer el estado nutricional de éste. El análisis foliar debe ser manejado con cuidado, pues se ha demostrado que las diferencias de concentración se deben frecuentemente al tipo de suelo, y características del sitio y no a un estado nutricional adverso.

(*) Escuela de Ciencias Forestales. Universidad de Chile. Casillla 9206. Santiago - Chile.

I.- INTRODUCCION

Las plantaciones de Eucalyptus en nuestro país, cubren una superficie cercana a las 60.000 ha., **Eucalyptus globulus** es la especie que ha sido plantada en mayor porcentaje y ha demostrado ser capaz de adaptarse a sitios de características muy variadas.

El informe elaborado por INFOR-CORFO (1986), estableció que junto a **Eucalytptus globulus**, se encuentran otras especies del género que han probado ser muy buenas alternativas para intentar su introducción masiva en distintas regiones del país, pues son altamente productivas. Este hecho junto a los resultados espectaculares logrados en Brasil, Sudáfrica y Nueva Zelandia, han motivado a las empresas forestales del país a estudiar la posibilidad de introducir especies como: **Eucalyptus regnans**, **Eucalyptus grandis**, **Eucalyptus nitens**, **Eucalyptus camaldulensis**, **Eucalyptus delegatensis** y subespecies de **Eucalyptus globulus**, concentrándose además en procedencias específicas para los sitios que disponen.

De esta manera, la demanda creciente por madera de fibra corta, producción de rollizos, madera aserrada, chapas, aceites esenciales y leña, pueden ser satisfechas por medio de Eucalyptus (Chile Forestal N° 106, 1984).

Aunque **Eucalyptus globulus** ha sido plantado desde comienzos de este siglo en nuestro país, ocupando superficies no muy extensas, sólo en los últimos 5 o 6 años, se ha intentado utilizar técnicas silvícolas que promuevan un mejor desarrollo de las plantaciones. A nivel experimental, se han fertilizado parcelas de ensayo, a veces combinando con preparación del suelo y controlando manualmente las malezas (TORO, 1987).

Las evidencias experimentales logradas en otros países han sido positivas (SCHONAU, 1984) y esto ha permitido que las empresas forestales estén incorporando mayores superficies de terreno para establecer plantaciones de Eucalyptus y desarrollar en ellos una silvicultura intensiva.

En el presente trabajo se analizan algunos resultados de experiencias chilenas, efectuados por INFOR, U. de Chile, FORVESA y CONAF VI Región entre 1982 y 1987.

El análisis se concentrará en plantaciones recién establecidas aunque se comentan brevemente ensayos en donde se controla deficiencia de boro, o bien fertilización en bosques más adultos.

La interacción entre preparación de suelo, control de malezas y fertilización se menciona solamente, pues es tratado con mayor profundidad en otro trabajo que se presenta en el Simposio.

II.- OBJETIVOS DE LA NUTRICION FORESTAL

Antes de entrar en el tema de los ensayos propiamente, se ha preferido concentrar algunos conceptos que ayuden a guiar la discusión final.

La **nutrición** se relaciona con el abastecimiento y absorción de compuestos químicos necesarios para el crecimiento y metabolismo de las plantas. Los compuestos requeridos por los vegetales se denominan **nutrientes** y son de naturaleza inorgánica, los cuales son aportados por el suelo (MENGEL y KIRKBY, 1982).

La **fertilización** tiene como objetivo aportar al suelo los nutrientes requeridos por la planta, en la cantidad, proporción, forma química y en la zona precisa para evitar desequilibrios nutricionales que alteren el metabolismo de la planta y lograr así un crecimiento adecuado de ella (HAUSENBUILLER), 1985).

A través de los fertilizantes, del control del agua, del mejoramiento de las propiedades físicas del suelo, puede mejorarse la productividad de éste. Por medio del material genético adecuado, del control de los agentes patógenos y de técnicas silvícolas adecuadas, es posible aumentar la productividad del sitio y de las plantaciones (PRITCHETT, 1979).

La fertilización forestal, en los trabajos que se comentan tiene como objetivo, ayudar a obtener una mayor productividad del futuro bosque.

De acuerdo a FLINN (1984), se distinguen cuatro tipos de fertilización; una denominada **"fertilización de apoyo"** que se efectúa al establecer o pocos meses después la plantación, tiene como objetivo dar un impulso nutricional que permita crecer rápidamente, para evitar la competencia con las malezas y ocupar a la brevedad el sitio; el segundo tipo es la **"fertilización correctiva"** que se emplea para corregir deficiencias nutricionales; el tercer tipo es la fertilización que se efectúa cuando el bosque se ha desarrollado cerrando las copas, generalmente al efectuar un raleo se combina con una fertilización; el cuarto tipo se refiere a la **"fertilización de reposición"** que se realiza en ecosistemas muy frágiles y que tiene como objetivo, restituir los nutrientes extraídos en la rotación anterior y evitar una reducción de la productividad.

En Chile se han efectuado para Eucalyptus, los tres primeros tipos y para **Pino** radiata, los cuatro tipos de fertilizaciones (TORO,1987).

III.- CICLAJE DE NUTRIENTES, PRODUCTIVIDAD Y OPORTUNIDAD DE FERTILIZACION

Según Weetman (1983), el término más adecuado para expresar la productividad es la productividad primaria neta (PPN) que es el producto de la fotosíntesis, una vez descontados los gastos por respiración. El ciclaje de nutrientes es una consecuencia de la distribución de la PPN a los distintos procesos de crecimiento, los cuales cambian de acuerdo a la edad del bosque.

Atiwill (1979) y Miller (1981), establecieron que el crecimiento del bosque debe ser considerado como una secuencia de tres fases bien definidos, que regulan la PPN y el desarrollo de la biomasa.

En la fase I, señalan ambos autores, la mayor proporción de la PPN se utiliza para construir el aparato fotosintético y hay una fuerte demanda por los nutrientes almacenados en el suelo. Es en este período donde la fertilización logra los mejores resultados (WARING, 1981).

La fase II empieza cuando las copas se han cerrado y la PPN se dirige en mayor proporción a la formación del duramen, la cual es un proceso regulador del crecimiento y no un signo de envejecimiento (BAMBER,1976). Aquí predomina un reciclaje interno de tipo bioquímico. Al efectuar un raleo y fertilizar a continuación, se logran resultados muy buenos en cuanto a crecimiento del rodal (MILLER, 1983).

La fase III es una de mantención cuando el bosque alcanza su madurez y los nutrientes son inmovilizados en la hojarasca; predominan procesos de tipo biogeoquímico. A veces, una fertilización da buenos resultados.

IV.- REQUERIMIENTOS DEL GENERO EUCALYPTUS

Este género ha evolucionado durante los últimos 60 millones de años, para adaptarse a condiciones de baja fertilidad del suelo y a climas con precipitaciones reducidas, siendo el primer factor el que controla la distribución de las diferentes especies (FLORENCE, 1984).

Se caracterizan por presentar bajos requerimientos de nutrientes, especialmente fósforo y las micorrizas ayudan a solubilizar formas de fósforo, no accesibles a las raíces (ATTIWILL, 1981).

Para elevar la productividad de un sitio, la fertilización es un medio eficaz, especialmente si se combina con la remoción del suelo y el control de malezas (SCHONAU, 1988). Según este autor, el tipo de fertilizantes y las dosis que se utilizan dependen más de las condiciones del sitio que los requerimientos de la especie; el equilibrio nutricional, en todo caso es fundamental.

Muchos suelos chilenos, cubiertos con plantaciones de Eucalyptus o bien disponibles para ser forestados, son de origen más reciente que los que se encuentran en Australia, Brasil, o Sudáfrica. No han experimentado una fuerte meteorización que signifique grandes pérdidas de elementos químicos del perfil del suelo. Sin embargo, el uso agrícola o ganadero intenso que tuvieron anteriormente ha desarrollado una fuerte erosión laminar y han perdido por lo tanto un alto porcentaje de materia orgánica que influye en la disponibilidad de nitrógeno (N), fósforo (P), azufre, (S) y boro (B), pues ellos se almacenan principalmente en la materia orgánica.

El subsuelo adquiere entonces gran importancia en la nutrición de los bosques cuando el sistema radicular ingresa a los horizontes subsuperficiales y las plantas son capaces de utilizar los nutrientes allí acumulados (COMERFORD et al, 1984). Una fertilización inicial puede desarrollar un istema radicular más vigoroso que permite explorar más eficientemente los recursos nutricionales.

Al fertilizar con nitrógeno, debe ponerse cuidado en el tipo de ión que se libera, pues según ATTIWILL (1979), el Eucalipto prefiere el catión amonio NH_4^+- N.

V.- ANALISIS DE ALGUNOS CASOS EN CHILE

La fertilización en Eucalyptus es una práctica reciente en nuestro país, aunque hay una gran cantidad de ensayos de tipo exploratorio, muchos de ellos recién establecidos, desconociéndose aún sus resultados preliminares. Los ensayos que se comentan, muestran por lo tanto una parte de lo que se realiza actualmente y se concentra en **Eucalyptus globulus** y un caso en **Eucalyptus delegatensis**.

5.1 Ensayos con tabletas de solubilidad controlada

En la VI Región se iniciaron en 1982 dos ensayos para observar el efecto de las tabletas; Omegna (1982) y Cabañas (1982) instalaron sus parcelas en el secano interior en dos sitios diferentes en suelos erosionados, con bajos niveles de materia orgánica (2,0%); con texturas franco arcillosos y franco arenosas; los niveles de nitrógeno (N), fósforo (P) y potasio (K) disponibles eran en promedio inferiores a 15 ppm, 6 ppm y 100 ppm respectivamente.

La tableta contenía N, P y K más microelementos y fueron colocadas cerca del sistema radicular del **Eucalyptus globulus**.

Al analizar las respuestas en la primera temporada, ambos encontraron que las plantas respondían tanto en altura como en diámetro de cuello, en porcentajes que superaban al testigo, aunque las diferencias no eran estadísticamente significativas al 95%.

Ambos autores coincidieron en que las limitaciones climáticas (7 meses de sequía) influían en la movilidad y absorción de los nutrientes. Recomendamos aplicar las tabletas en el período de otoño para obtener un mejor aprovechamiento del agua almacenada en el suelo.

5.2 Ensayos en plantaciones de seis años

También en la zona del secano interior de la VI Región (Topocalma) se efectuó otro ensayo, en donde la plantación tenía 6 años de edad a una densidad de 1.000 plantas/ha.

De acuerdo a Cornejo (1982), el suelo es profundo, de textura franco arcillosa, con un porcentaje de materia orgánica inferior a 2%; la reacción del suelo es de 5.5 y las disponibilidades de N, P y K son de 4 ppm, 2 ppm y 100 ppm respectivamente.

El nitrógeno se aplicó al voleo (400 y 600 kg/ha Urea). El fósforo se aplicó en forma localizada, empleándose sólo una dosis (200 kg/ha Superfosfato triple).

Al cabo del primer año, evaluó las respuestas y encontró que la combinación N-P (400-200) entregaba una respuesta en área basal superior en un 46% a la encontrada en las parcelas testigos. La aplicación de N y P en forma separada, entregaba respuestas positivas, pero inferiores a la combinación N-P.

Este ensayo será evaluado nuevamente en la próxima temporada.

5.3 Fertilización en monte bajo

En la V Región, Molina (1982) instaló un ensayo en un bosque explotado 4 veces, cuyos troncos eran de 40 años y los retoños tenían 2 años.

Al fertilizar con N (50, 100 y 150 kg/N/ha) y P (50-100 kg/ha) encontró al cabo de un año respuestas no significativas en diámetro ni en altura. Sin embargo, encontró que la combinación N-P aportaba incrementos superiores al testigo; en cambio al fertilizar sólo con P, los incrementos logrados eran inferiores al testigo.

5.4 Plantaciones de Eucalyptus globulus con deficiencias de boro

La deficiencia del microelemento boro es la única que se ha detectado en esta especie en sectores cercanos a Angol.

Un análisis foliar en plantaciones de 1 año señaló concentraciones de boro entre 1 y 4 ppm; las concentraciones de nitrógeno fluctuaban entre 0,84 y 0,48% y los de fósforo eran entre 0,06 y 0,08%.

Una aplicación de 20 gr de ácido bórico por planta, localizada a 20 cm de profundidad, controló el problema en los 5 meses siguientes, permitiendo un crecimiento vigoroso y sin síntomas visuales de N y P (TORO,1985).

5.5 Fertilización en sitios considerados normales

En 1986, se instalaron dos ensayos en sitios de diferentes características de la VIII Región (INFOR-CORFO), 1986).

El primero de ellos se estableció en El Almendro, predio cercano a Nacimiento. La textura del suelo es franco arcillosa, la reacción es de 6,3; el porcentaje de materia orgánica es de 2,8% y la disponibilidad de N, P y K es de 12 ppm, 5 ppm y 460 ppm respectivamente.

Los fertilizantes se aplicaron en forma localizada y las dosis de N en forma de Urea fueron 50 y 80 gr/pl Urea; el fósforo se aplicó localizado en una dosis de 40 gr/pl y también se adicionó boronatrocalcita 20 gr/pl y sulfato de potasio (50 gr/pl). En total se distribuyeron 14 tratamientos en un diseño factorial repetido cuatro veces.

Se encontraron al segundo año, diferencias significativas al 95% de confiabilidad para los incrementos en altura y diámetro de cuello, en **Eucalyptus globulus.**

Las combinaciones N, P,K,B dieron las mejores respuestas al igual que las combinaciones NP y NPB; en cambio al combinar PKB, exluyendo N, los incrementos obtenidos fueron inferiores en altura y diámetro a los logrados en el testigo.

El segundo ensayo se instaló en Colcura y se consideró sólo **Eucalyptus globulus.** La textura del suelo es franco arcillo arenosa en el primer horizonte y franco arcillosa en el subsuelo; el pH es de 5.2; el contenido de materia orgánica es de 4% y la disponibilidad de N, P y K es de 13 ppm, 1 ppm y 120 ppm respectivamente.

Los fertilizantes se aplicaron en la misma forma que en El Almendro, pero se emplearon otras dosis y fuentes, Urea (50 y 100 gr/pl), Superfosfato triple (40 gr/pl), Acido bórico (20 y 40 gr/pl); no se incluyó Sulfato de potasio.

Las respuestas fueron estadísticamente significativas al 95% en diámetro de cuello y altura.

Todos los tratamientos entregaron respuestas superiores a los testigos pero las mayores respuestas en altura, se encuentran en la combinación N_1B_1, N_2B_1 y PB_2. Una situación similar a la encontrada en El Almendro.

5.6 Sitios con problemas de sequías

En el predio Malvín, cerca de Nacimiento, VIII Región, se instaló un ensayo en 1982, para tratar de elevar el porcentaje de sobrevivencia y la tasa de crecimiento de **Eucalyptus globulus.** El suelo se caracteriza por tener texturas franco arenosa, pH cercanos a 5.3; un porcentaje de materia orgánica de 0,8% y una disponibilidad de nitrógeno, fósforo y potasio de 8 ppm, 3,5 ppm y 60 ppm respectivamente.

Se aplicaron dosis de Urea (80 y 120 gr/pl) y de Superfosfato triple (40 y 80 gr/pl), todas en un hoyo a 20 cm del suelo.

Al evaluar en el segundo año, se observó que todos los tratamientos entregaban porcentajes superiores al testigo y que las diferencias en altura eran significativas al 95%. Cuando se aplica N o P sólo en las dosis más altas, se obtiene incrementos que superan en un 50% a los no tratados; en cambio al combinar las dosis altas de N y P, el incremento en altura se duplica.

Al controlar el problema nutricional, permanece la restricción climática y las prolongadas sequías, afectan al desarrollo de la especie; una de las alternativas que puedan ofrecerse es el cambio de especies, por otra más tolerable a las sequías.

5.7 Fertilización en sitios de alta productividad

Los suelos derivados de cenizas volcánicas recientes son altamente productivos. En predios de FORVESA, ubicados en la VIII Región se ha determinado que **Eucalyptus delegatensis** es una especie muy productiva. A los 15 años presenta un volumen de 678 m^3, con un crecimiento medio anual de 45 m^3/ha.

En 1987, se instaló un ensayo en plantaciones recién establecidas y se aplicaron dosis de N, P y K en rangos similares a los efectuados en Colcura y El Almendro.

En Marzo 1988, sólo 7 meses después, von Mareé (1988) encontró respuestas significativas en diámetro y altura. La combinación NP y NPK fueron las que influyeron más en estas respuestas.

VI.- CONCLUSIONES

Como puede apreciarse, el **Eucalyptus globulus** responde a las aplicaciones de N y P solos o combinados según sean las características del sitio. En otras áreas es necesario aplicar K y B junto con N y P para encontrar respuestas más significativas.

Siempre la presencia de N está en las mejores respuestas, al estar ausente se deprime parte del crecimiento.

Es necesario además continuar con la evaluación de los ensayos mencionados pues debe conocerce la magnitud y duración de las respuestas para evaluar los aspectos económicos de la fertilización.

Eucalyptus delegatensis reacciona muy favorablemente a la fertilización y según von Marée (1988) puede lograrse un mayor incremento se controlan las malezas en forma más efectiva. La preparación del suelo no es necesaria en este sitio por las excelentes propiedades físicas del suelo.

REFERENCIAS BIBLIOGRAFICAS

1. ATTIWILL, P. 1979. Nutrient cycling in a **Eucalyptus obliqua** Forest; III Growth, biomasas and net primary production. Aus. J. Bor. 27, 439-458.

2. ________ 1981. Energy, nutrient flow an biomass. Proceeding of of Australian Forest Nutrition Work Shop. Camberra. pp. 131-144.

3. BAMBER, R. 1976. Heart wood, its function and formation. Wood Sci. and Tech. 10:1-8.

4. COMERFORD, N.; KIDDER, G. and MOLLITOR, A. 1984. Importance of subsol fertility to forest. In : E.L. Stone (ed) Forest Soils and Treatment Impacts. Proceeding of the Sixth North American Conference : 381-399.

5. CABAÑAS, C. 1982. Análisis comparativo entre fertilización mineral tradicional y por módulos en **Eucalyptus globulus.** Tesis de Grado, Fac. de Ciencias Agrarias, Veterinarias y Forestales, U. de Chile. 108 p.

6. CORNEJO, B. 1982. Respuesta de una plantación de **Eucalyptus globulus** a la fertilización con Urea y Superfosfato triple en la Comuna de Litueche, VI Región. Tesis de Grado, Fac. de Ciencias Agrarias y Forestales, U. de Chile. 91 p.

7. FLINN, D. 1984. Practical aspects of the nutrition of exotic conifer plantations and native Eucalypt forest in Australia. In: Sandberg, J. and Parson, W. (ed). Research for Forest Management. Camberra. pp. 73-154.

8. FLORENCE, R. 1984. Eucalypts, sites and Silviculture. Proc. IUFRO Symp. Site and Productivity of fast growing plantations. Pretoria and Pietermarrtzburg (2) : 609-619.

9. HAUSENBUILLER, R. 1985. Soil Science : Principles and Practices. Wm. C. Brown Publishers. Third Ed.

10. HILLIS, W. and BROWN, A. 1984. Eucalyptus for wood production. CSIRO-ACADEMIC PRESS.

11. MENGEL, K. and KIRKBY, E. 1983. Principles of plant Nutrition. 3er. Ed. Intenn. Potash Inst. Bern. Switzerland.

12. MILLER, H. 1981. Nutrient Cycles in Forest Plantations. Their change with age and the consecuence for fertiliser practice. Proceedings of Australian Forest Nutrition. Workshop, Camberra : 187-199.

13. __________. 1983. Maintenance and Improvement of Forest Productivity an overview. In : IUFRO Symposium on Forest site and Continuous Productivity. Ed. R. Ballard and S.P. Gessel : 280-285.

14. MOLINA, H. 1982. Estudio de fertilización en monte bajo de **Eucalyptus globulus**, en la provincia de San Antonio. Tesis de Grado. Facultad de Ciencias Agrarias, Veterinarias y Forestales, U. de Chile. 143 p.

15. OMEGNA, A. 1982. Aplicación de módulos fertilizantes en especies forestales **Eucalyptus globulus** y **Pinus radiata** en la VI Región. Tesis de Grado. Facultad de Ciencias Agrarias, Veterinarias y Forestales, U. de Chile. 98 p.

16. SCHONAU, A. 1984. Fertilization of fast-growing broad llaved species. Proc. IUFRO Symp. Site and Productitivy of fast-growing plantations, Pretoria and Pietermaritzburg (1) : 253-268.

17. SCHONAU, A. y HERBERT, M. 1988. Fertilizing Eucalyptus at plantation establisment. In : Simposio Manejo Silvícola del Género Eucalyptus. INFOR-CORFO. Santiago, Chile. 26 p.

18. TORO, J. 1985. Fertilización mineral en plantaciones con crecimiento restringido y en rodales de buena calidad. Informe N° 4. Convenio Asistencia Técnica Forestal Río Vergara S.A. y Facultad de Ciencias Agrarias y Forestales, U. de Chile. Mimeografiado. 37 p.

19. ________ 1987. La Fertilización Forestal en Chile, avances logrados hasta 1987. Art. Téc. Chile Forestal N° 143, Sept. 1987 : 27-30.

20. WARING. H. 1981. Forest Fertilization in Australia : early and late. Proceedings of Australian Forest Nutrition Workshop, Camberra : 201-218.

21. WEETMAN, G. 1983. Ultimate forest productivity in North América. In : IUFRO Symposium on Forest Site and Continuous Productivity. Ed. R. Ballard and S.P. Gessel : 70-79.

22. VON MAREE, A. 1988. Respuesta a la fertilización con NPK de una plantación recién establecida de **Eucalyptus delegatensis** en la precordillera andina de la IX Región. Tesis en elaboración. Facultad de Ciencias Agrarias y Forestales, U. de Chile.

XII

LA IMPORTANCIA DE LA PREPARACION DEL SITIO Y LA FERTILIZACION EN EL ESTABLECIMIENTO DE PLANTACIONES DE EUCALYPTUS

José Antonio Prado D.(*)
Johannes Wrann H. (*)

RESUMEN

Existe un creciente interés en el establecimiento de plantaciones de especies del género Eucalyptus.

El establecimiento de **E. globulus** en la zona semiárida presenta dificultades. Para asegurar una buena supervivencia y crecimiento inicial es necesario aplicar métodos que favorezcan el desarrollo radicular y reduzcan el efecto de la competencia.

Entre los tratamientos de preparación del suelo, el surco es el más efectivo.

La aplicación de herbicidas aparece como la mejor opción para asegurar una buena supervivencia y desarrollo inicial en la zona semiárida.

La fertilización afecta positivamente el crecimeinto de las plantas, pero debe aplicarse en conjunto con el herbicida, de lo contrario puede tener un efecto negativo en la supervivencia. Los tratamientos que combinan una buena preparación de suelo, con herbicida y fertilizante, producen crecimientos significativamente superiores.

Palabras claves : Preparación de sitio, Herbicida, Fertilización.

(*) Ingeniero Forestal. División Silvicultura. Instituto Forestal - Filial CORFO. Huérfanos 554. Santiago - Chile.

1.0 INTRODUCCION

Después de varias décadas en que el interés de las grandes compañías y forestadores estuvo casi exclusivamente centrado en **Pinus radiata**, ha surgido una tendencia hacia la diversificación de especies en las plantaciones forestales. Esta es la respuesta a 3 necesidades fundamentales que son: la diversificción de los productos forestales, para poder acceder a nuevos mercados; el aprovechamiento de aquellas áreas que no son adecuadas para el Pino Insigne y finalmente, la diversificación ante la eminente amenaza de algunas plagas sobre el monocultivo de **Pinus radiata**.

Los resultados obtenidos en el Programa de Introducción de Especies desarrollado por el Instituto Forestal (INFOR - CORFO, 1986) señalan al género Eucalyptus como la gran alternativa para la forestación bajo diversas condiciones, desde la semiaridez de la zona central hasta los climas lluviosos y fríos presentes más al sur.

El establecimiento de bosques de Eucalyptus en este amplio rango de condiciones de sitio presenta dificultades. En la zona central, las condiciones de suelo y clima imponen un medio muy riguroso para el establecimiento de plantaciones, por lo que la aplicación de métodos adecuados para proveer a la planta de un medio favorable para su desarrollo inicial, especialmente de sus raíces, no sólo es recomendable sino que resulta indispensable. Está demostrado que los métodos tradicionales de establecimiento empleados en la zona semiárida no son suficientes para asegurar una buena supervivencia y un rápido desarrollo de las plantaciones (Prado y Rojas, 1987; Wrann e Infante, 1988).

En la zona sur, en donde las condiciones son más favorables, el establecimiento de plantaciones de Eucalyptus también presenta dificultades.

La supervivencia y el crecimiento inicial se pueden ver fuertemente afectados por la competencia de la vegetación arbustiva y principalmente del pasto. La mayoría de las especies de Eucalyptus recomendadas para su plantación en Chile son muy susceptibles a la competencia que por luz, agua y nutrientes imponen las especies competidoras.

Cromer (1984) sostiene que la causa más importante de mortalidad en plantaciones es la presencia del pasto.

Es por esto que la preparación del sitio resulta de fundamental importancia, bajo cualquier condición. El mejoramiento de las condiciones del suelo, tanto físicas como nutricionales, y la eliminación de la competencia, permiten aprovechar en mayor proporción la potencialidad del sitio para desarrollo de la plantación.

Cuando la fertilidad del suelo es una limitante se recurre a la fertilización. Las especies del género Eucalyptus presentan una muy buena respuesta a la fertilización realizada al momento del establecimiento. Una amplia disponibilidad de nutrientes permite un rápido desarrollo radicular, dando ventajas a las plantas que pueden manifestarse a lo largo de toda la rotación.

Con el fin de evaluar el efecto en distintos tratamientos de preparación del sitio, incluyendo fertilización, el Instituto Forestal ha establecido diversos ensayos, cubriendo distintas condiciones de suelo y clima. Los resultados obtenidos en dos de ellos se evalúan en este trabajo.

2.0 MATERIAL Y METODO

Con el objeto de cubrir diversas condiciones de suelo y clima a lo largo del área susceptible de ser plantada con especies del género Eucalyptus, se ha establecido una serie de ensayos, desde la zona árida, en la IV Región, hasta zonas muy favorables para el desarrollo de plantaciones, en la VIII Región.

Para este análisis se han elegido 2 de ellos, por considerarlos representativos de condiciones semiáridas y húmedas, respectivamente.