Liaison

NEWSLETTER

NATIVE PLANT REGENERATION STUDY GROUP
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“ ? “

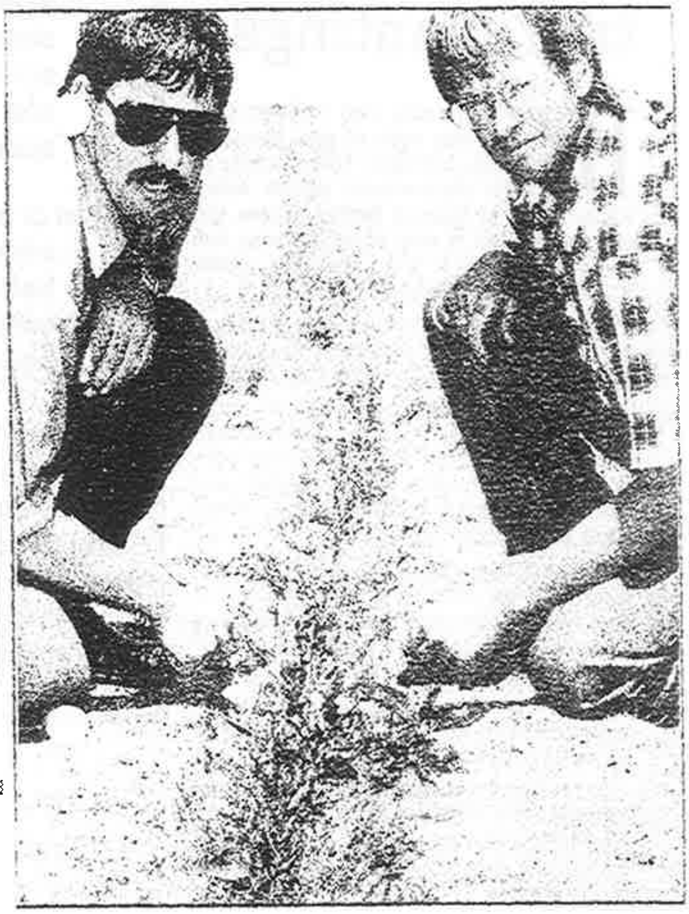
Can you put a picture in the space above ?

Why not send one in for a bit of fun

Editorial

At this time of year I start to think about the seed collection and where might I find the best source of seed in the region of the state that I am in.

Most of you may start the collection of seed in latter parts of the year or may already been collecting seed for the next years plants. In my cases the plants that I am after produce their seed in summer month (mainly Acacias).



Woods and forest Officers Kent Rohde, left and Rod Burford inspect the results of direct tree seeding on the Army Range using Bitumen as described in the article on page 2

Currently I have been run of my feet in readiness for the end of year for both revegetation and along with work commitments. I have recently done a letter to all members of the study group along with past members with information on what we have done in the last twelve month in the way of newsletters. I would like to get all members together for an event to discus ideas or to demonstrate new ideas and concepts for people. The letter is also to act as a way of increasing our membership to increase the wonderful input we have so far enjoyed.

The copy deadline for the next newsletter is mid February for a March Newsletter. Sent articles, newspaper clippings cartoon or logos that have been supporters or aided in revegetation to

P.O. Box 2089
Normanville
SA 5204

Cheers

Matt Pearson

Bitumen boosts tree plantings

BITUMEN is being used to boost tree establishment rates at sites throughout South Australia. One of these is the arid environment of the Army Range, east of Murray Bridge, where the average rainfall is only 325mm a year but where thousands of trees are being established by direct seeding.

The single furrow direct seeding of 37.5km at the range last year was one of the biggest tree-seeding operations of its type in SA.

"Using our Roden 111 seeder we spray bitumen as a mulch after the seed has been placed in the furrow and after it has been pressed by the press wheel," Woods and Forest Department revegetation officer Kent Rohde said.

"All this happens in one pass. The bitumen holds the seed, attracts heat, stops the ants from carrying the seed away and acts as a mulch by preventing evaporation.

"In light soil it also stops the trench from blowing in. Our research shows you get better establishment in this sort of climate by using bitumen."

In 1991, an estimated 13 million trees were established — 4 million by direct seeding, a significant increase on the previous year, mainly because of the lower cost and ease of direct seeding.

QUALITY ASSURANCE PROGRAM FOR REVEGETATION

To carry out this snap shot survey of how success full we are at revegetation I need to know the following -

- Soil Type
- Rainfall
- Species of plant
- What type of tree guard use if any
- If a herbicide was used if any fertiliser used if any
- Burning the area prior to planting
- What method of planting was used.
- Information on what the growing conditions were like e.g. was dry year on a north facing slope and I had 70% survival of species X and 20% survival of species Y
- And or any other relevant information that will be help full. In the third edition of this newsletter

All information will published hear in the newsletter of the Native Plant Regeneration Study Groups and other newsletters. and also a copy of the information will be sent to you for participating in the survey

IF YOU HAVE AN IDEA OF AN INTERESTING PIECE OF INFORMATION THAT CAN FILL THIS SPECIE PLEASE SHARE IT WITH THE REST OF THE GROUP FOR WE ARE ALL INTERESTED IN REVEGETATION OR REGENERATION

RESEARCH

Reporting important findings relevant to the restoration of tree cover in Australia's cooler regions.

TREE PLANTING IN COLD CLIMATES — LESSONS FROM FUNDAMENTAL RESEARCH

JOHN EGERTON — Research School of Biological Sciences, A.N.U., Canberra, Australian Capital Territory.

Abstract

There are many difficulties faced when attempting to establish trees on cleared land in cold climates. This report provides insights gained through fundamental research undertaken by the Ecosystem Dynamics Group at the Australian National University in Canberra. Undoubtedly frost is a major detrimental factor affecting tree establishment in cold regions. However, if shade is provided during winter, frost is less damaging. Secondly, tree seedlings surrounded by damp bare soil during winter can be significantly warmer at night than seedlings surrounded by short grass. Subsequent growth in spring is then enhanced by not being near grass. The provision of shade and the need to remove neighbouring grass show how conditions during winter cannot be dismissed. The immediate microclimate experienced by seedlings during winter therefore has important implications for survival and growth during spring and summer.

Key Words: Frost, photoinhibition, microclimate, ***Eucalyptus****, tree guards, grass, cold, seedling establishment, rural tree decline.*

Like elsewhere in Australia, rural tree decline in higher elevation regions is a real concern. Especially on private land, clearing has been extensive and many of the remnant trees remaining in the tableland regions of eastern Australia have been dramatically affected by dieback (Kile, 1981). There is strong evidence that dieback is more widespread where clearing has been undertaken, compared to the levels of dieback in intact forests (Landsberg *et al*., 1990). Following clearing, the remaining trees experience temperatures that are both hotter and colder, and are exposed to more solar radiation for longer periods. Curiously, the role that these changes might play in the onset and severity of dieback, has received very little attention. It is recognised that insects are often the most obvious cause of dieback; however, the link between modification of environment associated with the removal of the original forest cover and subsequent insect attack is poorly understood.

Soil erosion is also a serious problem in many cold regions. Soil stabilisation has been a major issue in the Snowy Mountains in the past, and in areas such as the Monaro, soil loss is considered to be extensive (Costin, 1954). In order to halt these problems, tree planting schemes have been initiated (Beresford, 1984). However, the successful establishment of tree seedlings in colder areas has a special set of problems.

Although cold is undoubtedly an extremely important factor in determining the success of a tree planting project, recent studies have shown that it is extremely important to provide shade during stressful conditions such as frost. Tree planting is expensive and methods which improve survival and growth are continually being sought. Dr Marilyn Ball in the Ecosystem Dynamics Group at the Australian National University (ANU) leads a research team which has shown that shading seedlings during winter enhances survival and spring growth (Ball, 1994).

It must be stressed that the initial work from this group was primarily serendipitous. The applied benefits that stem from this work are a by-product of fundamental research aimed at understanding (1) how plants use light and what are the mechanisms for protection from excess light under varying environmental conditions, and (2) how such physiological attributes relate to regeneration under natural and altered microclimates.

Traditionally, growth of cold-climate plants is considered to be related to duration of the growing season rather than the length and severity of winter. These ideas need to be revised, especially for evergreens. Conditions in winter directly influence plant performance later in spring and summer.

A comparison between the microclimate experienced by a tree seedling in a forest and in an open pasture goes some way to explaining why it is often difficult to establish seedlings on farmland. On the forest floor temperatures are generally not as hot, or as cold, as a corresponding area in the open (Nunez and Bowman, 1986). A tree canopy acts as an insulating layer, so that at night, heat loss is lessened and during the day the amount of energy received near the ground is reduced. It has been shown that the minimum temperature that a

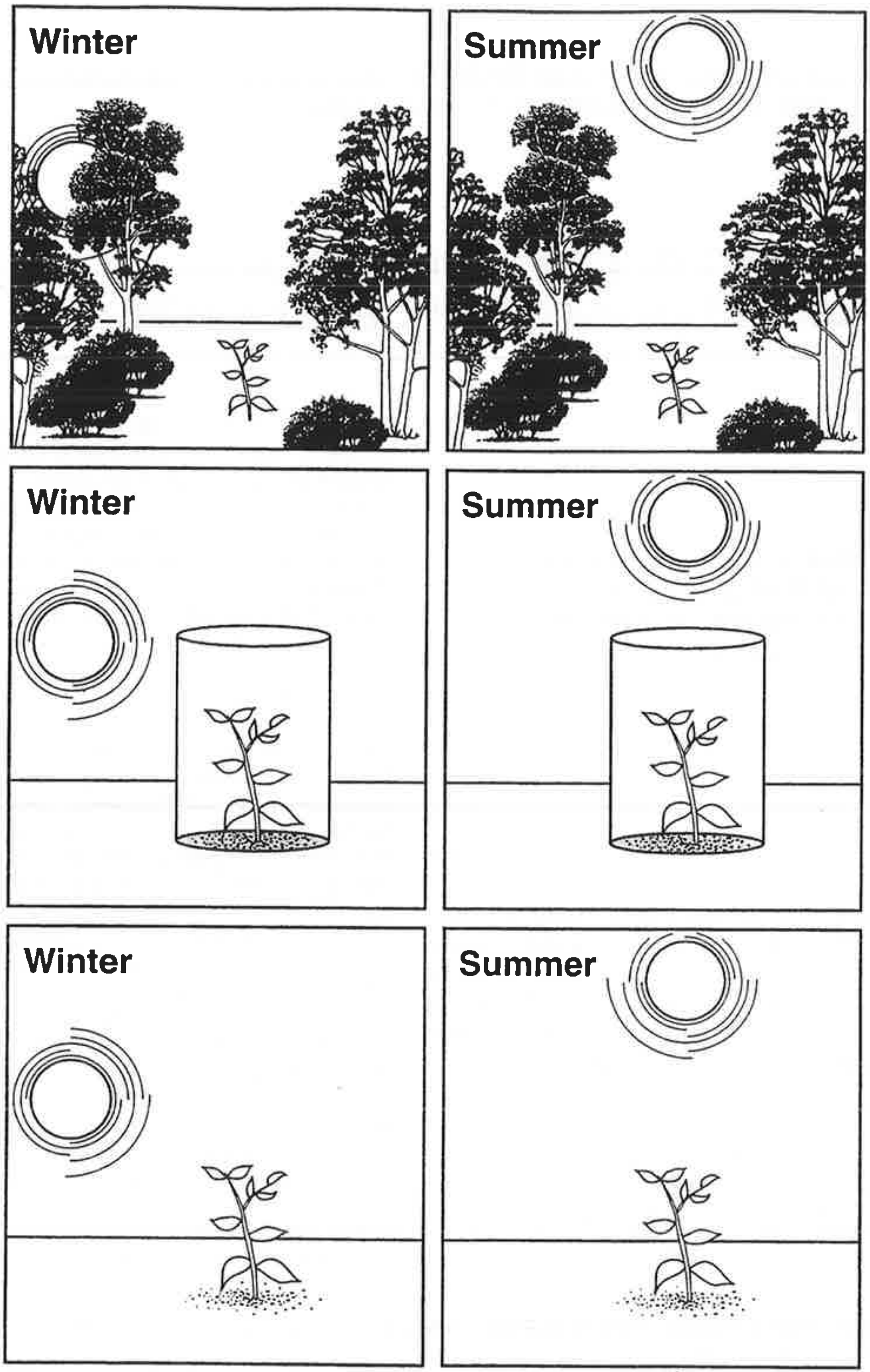


Figure 1. A seasonal comparison between the light environment of a seedling in either a forest gap, an open-topped shelter, or a pasture.

tree seedling may experience in a forest is closely related to the amount of clear sky directly overhead (Jordan and Smith, 1994). In other words, a complete tree canopy will result in higher minimum temperatures near the ground, than comparable locations in the open.

Obviously the light environment is drastically altered once the tree cover has been removed. Even in a large forest gap, a newly established tree seedling will receive less sunlight compared to an open pasture. In winter when the sun is relatively low in the sky, direct sunlight will reach the ground either for a short period, or not at all. However in summer, when the sun is higher, the ground in forest openings will be exposed to much longer periods of direct sunlight (Fig. 1).

Considering how different the conditions are in pasture compared to in the forest, it is little wonder that trees which normally regenerate in a forest environment, have trouble in surroundings that have been extensively altered. In winter, a regenerating tree seedling under natural forest conditions would rarely be exposed to both frost and direct sunlight first thing in the morning.

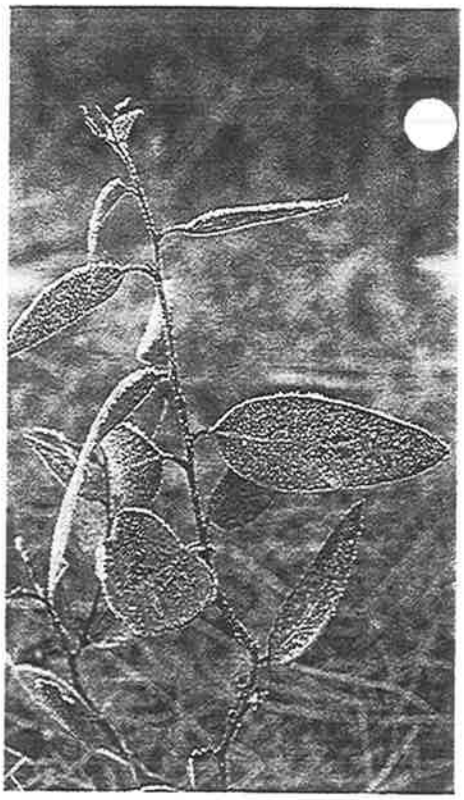
FACTORS INFLUENCING COLD CLIMATE TREE ESTABLISHMENT

Frost

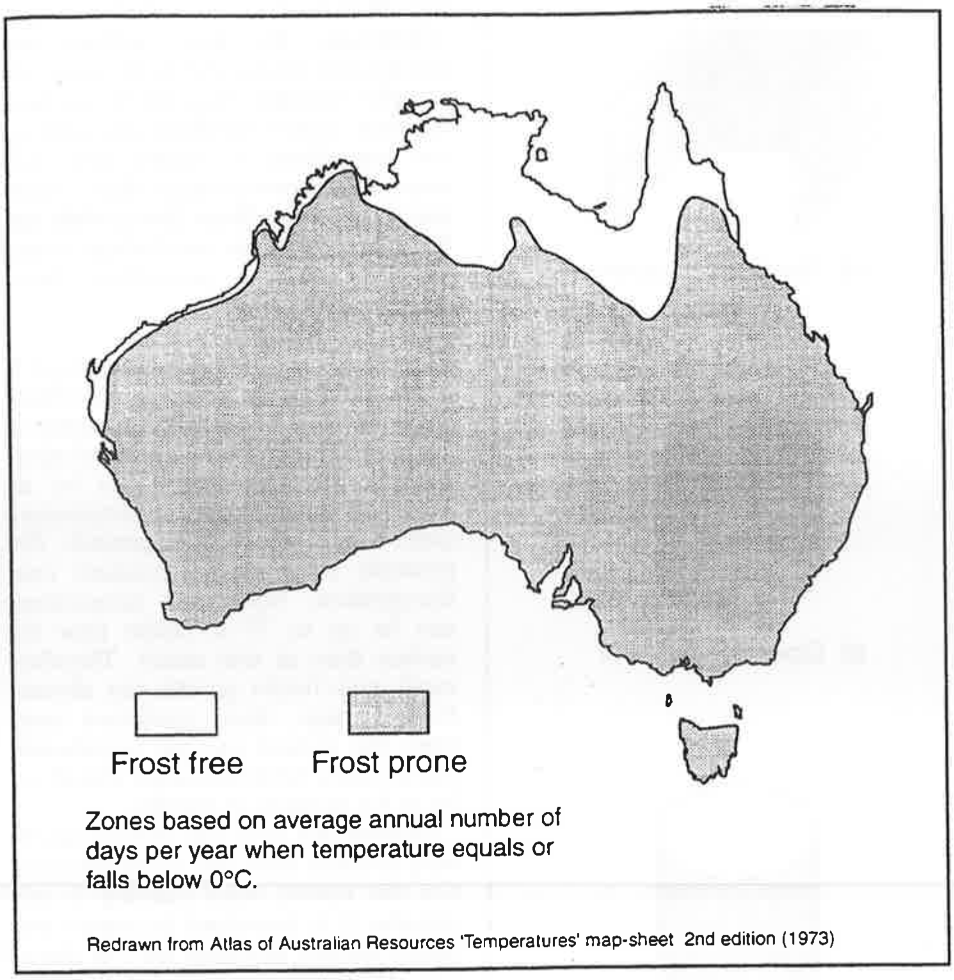
Although Australia is quite rightly considered to be generally hot and dry, long term weather records show that a considerable proportion is prone to frost for at least some period during winter (Fig. 2). In temperate regions, frost can be most damaging during spring and autumn. Field-grown plants normally withstand lower temperatures during winter than at other times of the year. Unseasonal frost when plants are unhardened can be most damaging. Nevertheless, extreme low temperatures in winter can also be responsible for widespread damage. Frost is regarded as a major factor limiting tree establishment in cold climates. However, frost in combination with bright sunny days is a major cause damage and mortality.

Light

Sunlight is considered to be one of the major factors determining plant growth. For light demanding species such as *Eucalyptus*, full light is generally considered to be beneficial. However, like fertiliser and water, too much light can be detrimental. Under stressful conditions such as extremes in temperature, drought and salinity, a plant's capacity for photosynthesis can be reduced. Such losses are magnified in plants exposed to high light. This light



• Frosty snowgum seedling.

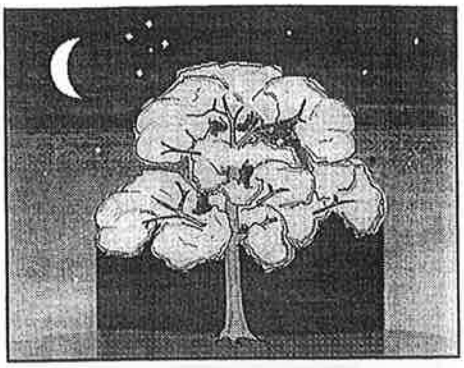


Zones based on average annual number of days per year when temperature equals or falls below 0°C.

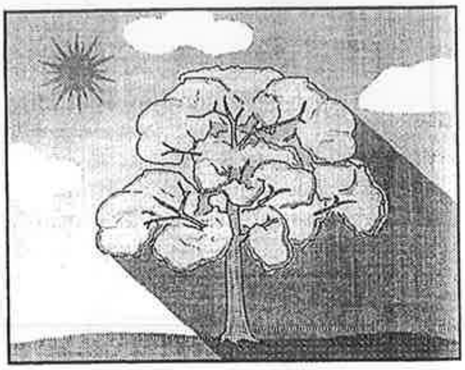
Redrawn from Atlas of Australian Resources 'Temperatures' map-sheet 2nd edition (1973)

Figure 2. Frost prone areas in Australia.

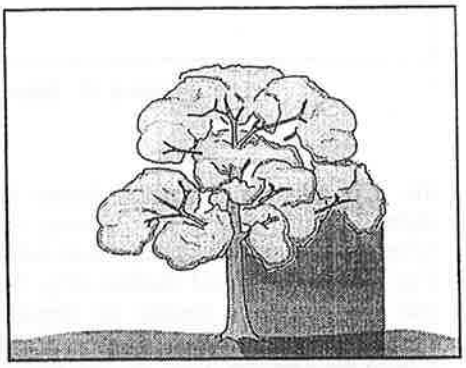
Figure reproduced with permission from 'Biologic' No.9 (1994) as redrawn from the original in Ball *et al.* (1991)



a) The microclimate beneath a canopy is warmer than in the surrounding exposed areas, due to protection from heat loss by radiation.



b) The canopy provides protection from intense exposure to winter sunlight on the southern side of adult trees.



c) The combination of these two factors creates a regeneration niche for seedlings and is consistant with the asymmetry of seedling distribution found around adult trees in the field

Figure 3. Combination of protection from radiation frost and intense winter sunlight provides a reason for the asymmetric distribution of seedlings.

phenomenon is known as photoinhibition and can be defined as a light-dependent loss in photosynthetic efficiency (Krause, 1988). In other words, photoinhibition occurs when more light energy is absorbed than can be utilised or dissipated by normal photosynthetic processes (Osmond, 1994).

An example of how photoinhibition can influence the way in which seedlings grow and regenerate is in the Orroral Valley near Canberra. This valley once supported a forest until it was cleared for grazing except for a small number of widely scattered trees. This area is now part of Namadgi National Park where grazing is not permitted. Snow gums are now regenerating slowly, however it is the pattern of regeneration that is most intriguing. Along the floor of the Orroral Valley winter minimum temperatures often fall to around -8°C and on extreme nights air temperatures can fall to -18°C. What is interesting is that the distribution of juvenile seedlings was consistent with their vulnerability to cold-induced photoinhibition (Ball *et al.*, 1991). The highest density of seedlings occurred beneath the canopy of the remaining scattered trees where it is warmer during the night than in fully exposed locations. Seedlings under these canopies were clustered on the southern sides where there is protection from direct morning sunlight in winter when the solar angle is low and the sun follows a northerly path. It seems as though these sites are favoured as they provide protection from both extreme minimum temperatures and direct light first thing in the morning (Fig. 3).

Therefore in frosty conditions plants have trouble utilising high light and are prone to damage. If possible, shade should be provided during frosty periods.

Artificial Shade Shelters

There are a number of different possible shade shelter designs. Depending on the type of construction, microclimate within the shelter can be significantly altered. There are a number of different possible materials that can be used. The first alternative is shade cloth which can be relatively expensive yet can be modified extensively into a range of different designs (Fig. 4). Shade cloth is normally available in densities of 30, 50 and 70 per cent. That is, 30 per cent shade cloth cuts out less light than 70 per cent. A range of different studies at the ANU have shown that 50 per cent shade cloth is generally the most favourable density available.

If screens (Fig. 4a) are to be used they should be placed close to, and orientated to the north of seedlings to ensure that maximum shade is provided. Using this design there is likely to be very little modification of overnight minimum temperature (Lundmark and Hällgren, 1987). Three-sided screens (Fig. 4b) should be orientated so that the open side faces south. Using this layout

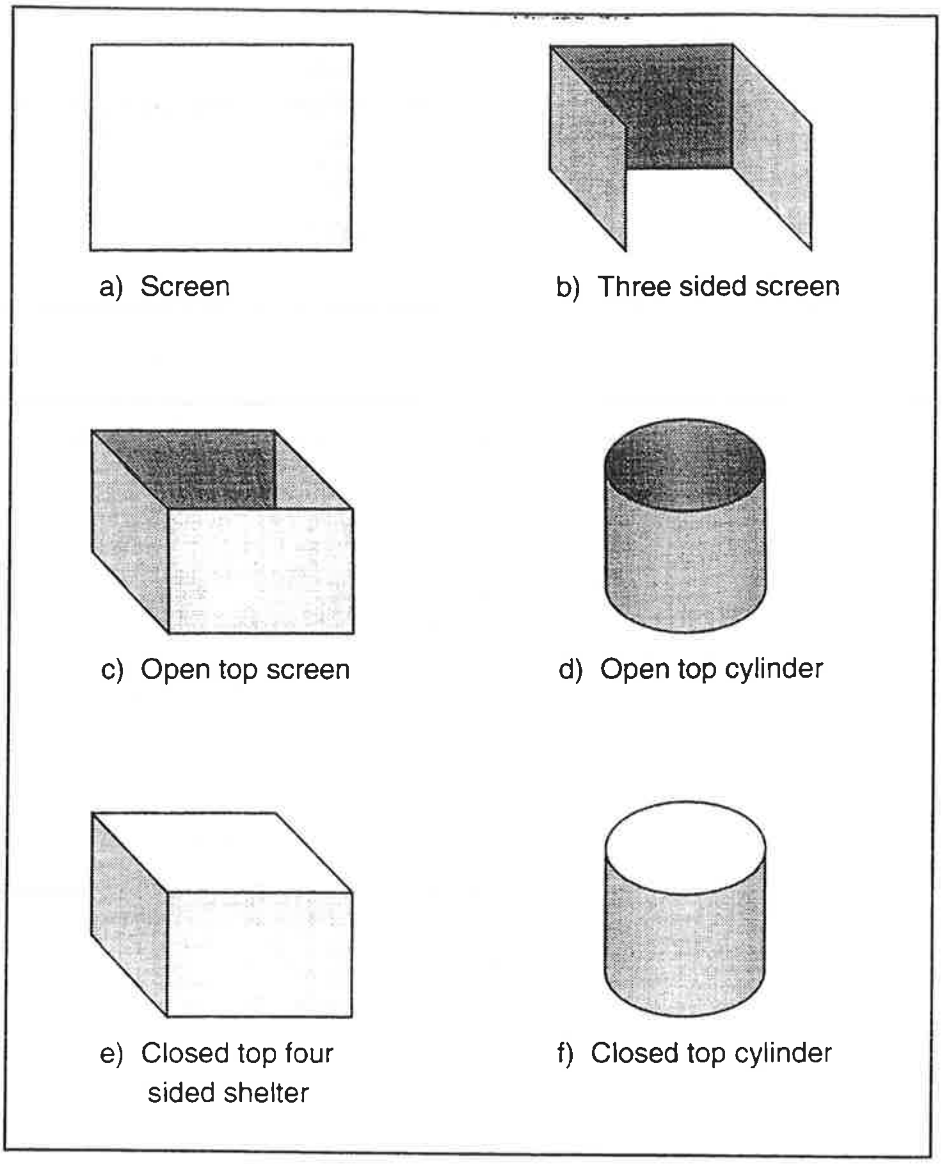


Figure 4. Shade shelter designs.

the interior of the shelter should be slightly warmer during the evening. Air temperatures in open-top four-sided (Fig. 4c) or cylindrical shelters (Fig. 4d) can be up to a couple of degrees warmer at night (Holly *et al.*, 1994). Closed top shelters (Figs. 4e and 4f) are even warmer. Closed-top shelters, however, have the disadvantage of becoming too hot during the day, primarily because of limited air circulation. Closed-top shelters are also limiting in that they quickly become too small as seedlings are unable to grow out of the top. Therefore they can only be used for a short period, say a year or two, or the tops need to be cut out when the seedlings have reached the roof of the shade shelter. Other than shade cloth, other items can be used, such as tyres, petrol drums, forklift pallets, or anything available that has the potential to provide shade during frost.

The role that tree shelters play in damping down sunlight during frost has been given little attention. Holly *et al.* (1994) investigated a range of different tree guards constructed of different materials in order to determine their influence on tree seedlings. Results showed that if tree seedlings were surrounded by 50 per cent shade cloth over winter, then growth in spring was significantly enhanced.

Natural Shade

There is growing evidence that plants often benefit from one another (Hunter and Aarssen, 1988). Larger plants can sometimes be considered to be nurse plants for newly emergent seedlings. So when light conditions in an open pasture are compared to the solar environment in a forest gap, it is not surprising that tree seedlings in pasture are especially prone to photoinhibition following frost. Practical alternatives are multispecies plantings which include both fast-growing, short-lived shrubby species and slower growing tree species. Ideally shrubs will shade tree seedlings when they are small and most vulnerable to frost damage. If possible, when planting, ensure that the shrubs are placed north of the tree seedlings, as this will maximise winter shade.

Eventually the tree saplings will overtop the shrubs and as the trees will be older and taller, they will be less frost sensitive. Larger seedlings and saplings are more likely to modify their own immediate environments than newly planted small seedlings. Due to their size they self shade their own foliage, which affords greater protection from photoinhibition.

Site Preparation

The environment near the ground is often dramatically different to official measurements of temperature made in weather screens at meteorological stations. At night there can be an extremely steep gradient in temperature with height above the ground. For example in a cleared pasture near Bungendore, NSW, the temperature can be up to 7° C colder near the surface than at one metre. Therefore rapid early height growth can alleviate frost damage, since conditions away from the ground can be considerably milder. Early height however, should not be at the expense of stability.

Microclimate near the ground can be very different over very short distances. For this reason when planting in cold climates it is important to ensure that newly planted seedlings are not placed into depressions or holes of any kind (Cremer, 1990). A newly planted seedling sitting in a small depression can be subject to a pool of cold air during winter evenings due to cold air drainage.

In winter it is important to provide a patch of bare ground surrounding young seedlings. If soil is moist, then minimum

• Mid-winter frost, Orroral Valley, ACT.

temperatures above soil can be significantly warmer than above grassy surfaces (Leuning and Cremer, 1988). This can be explained by the fact that damp soil has the ability to store heat during the day and at night this heat is released. On the other hand, vegetated surfaces are less able to retain heat during the day, because they generally have much smaller thermal mass, and in the evening lose their heat very quickly. A material's ability to retain heat is related to its ability to absorb and retain energy. If soil is dry it has a lower heat capacity. Seedlings growing in a patch of bare, moist soil experience less frequent and less severe frosts than seedlings surrounded by grass.

For reasons outlined above, placing mulch around and beneath the base of new seedlings is to be avoided, at least during frosty periods. Mulch also has low heat capacity. Undoubtedly mulch has many benefits which include controlling grass and weed competition, conserving soil moisture and aiding soil fertility. However during colder seasons mulch can effectively chill newly planted tree seedlings. A possible solution is to avoid addition of mulch until after new seedlings have reached the frost free period of the year. Mulch or litter in a forest is likely to have a very different effect because a tree canopy is an effective insulating layer. As described earlier, minimum temperatures inside forests are normally higher than corresponding areas in the open.

Like mulch, a grassy surface beneath a seedling is much colder than damp bare soil. Grass acts as an insulating layer so that during the day in winter, soil beneath a grassy sward is restricted from warming. Grass itself also has very little thermal mass and has a low heat capacity. So far discussion of the influence of grass has been in terms of grass that is short or is primarily beneath a young tree seedling. The influence of long grass in modifying the immediate microclimate of a tree seedling is very different. Long grass if at the same height, or taller than the planted tree seedling, is likely to act as a layer of insulation. Light levels are also restricted so that especially during winter, photoinhibition is less likely. However it is well recognised that during other times of the year grass growth should be restricted as far as possible due to competition.

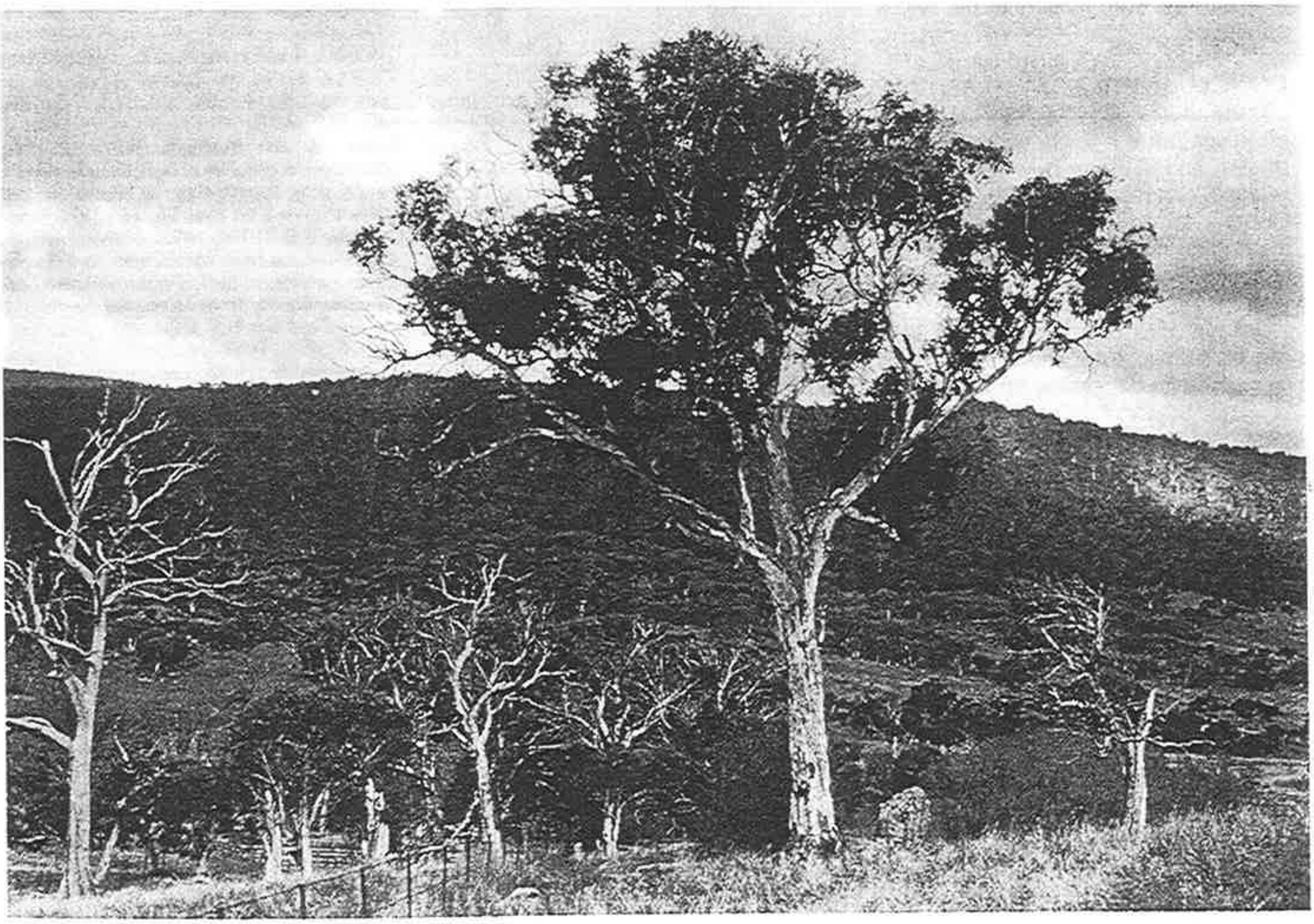
Aspect

Aspect can influence microclimate at a broader scale than mentioned above. Although it is recognised that sheltered east and south facing slopes provide conditions that are moister and cooler than corresponding west and north facing slopes, influence of aspect varies with season.

Generally, survival during winter on southern aspects is higher, than either east, west or northerly aspects. This may be because southern facing slopes do not receive direct sunlight first thing in the morning when it is frosty. This may allow seedlings to avoid conditions which are likely to produce photoinhibition, that is, frost and high light. With respect to other aspects it is more difficult to make generalisations. West facing slopes in winter are less likely to suffer from frost damage than east facing slopes because they are not exposed to the combination of high light and freezing temperatures. This is because west facing aspects normally warm up before they are exposed to direct sunlight later in the day.

Non Growing Season

Normally conditions during winter are considered to have very little influence on subsequent growth. Nothing could be further from the truth. The conditions in each season have a lingering effect on the next. During winter it is important to maintain soil moisture in order to keep seedlings warm. As mentioned earlier, for a tree seedling to benefit thermally



• Much of the higher elevation forest cover in Australia is considerably fragmented.

from being located in a large bare patch, soil cannot be dry.

Near Canberra, results of two studies in progress show effects of winter on spring growth of snow gum seedlings. A PhD student, Jenifer Butterworth has found that snow gum seedlings which are partially shaded during winter, and then exposed to full sunlight in spring, achieved twice the growth of seedlings which received full sunlight in both winter and spring. In a parallel study, Dr Marilyn Ball and colleagues found that microclimate above a cold grass surface adversely affects spring growth, with exposure to lower temperatures during winter leading to a 17 per cent reduction in spring growth. These results emphatically show that conditions in winter cannot be discounted, as they directly modify growth in spring.

Transplant Shock

Need to preharden. If possible, transfer plants to site prior to planting and store in the open near the ground. It seems that plant orientation may be important. Ensure that plants when placed into the ground have the same orientation as when they were in the nursery. A possible aid here is to mark the orientation of seedlings while in the nursery. By doing this, change in light environment from nursery to the field is minimised.

CONCLUSIONS

These notes stem from both basic photosynthetic and microclimatic studies, and illustrate how fundamental research can have far reaching benefits. Good theoretical research has application not only to developing new scientific ideas but to applied areas as well.

These studies also illustrate that light can be both a stress and a resource to tree seedlings depending on the season and their immediate microenvironment. Under cold conditions high light for newly establishing seedlings should be avoided. However at milder times of the year, trees that are normally considered to be light demanding have little trouble utilising full sunlight.

The influence of grass on tree seedlings includes not only traditional ideas concerning competition, but also modification of microclimate. The way in which tree seedlings can be effectively chilled by underlying grass, during winter, challenges present ideas about the way in which trees and grass interact with one another.

The ideas presented here highlight how the conditions during winter have an overwhelming influence on the eventual success of tree planting schemes in cold climates. It must be stressed, however, that these ideas need to be further refined before being put into practice and they should not be considered to be hard and fast prescriptions. Nevertheless they provide tantalising methods which should improve the overall success of tree planting in cold climates.

ACKNOWLEDGMENTS

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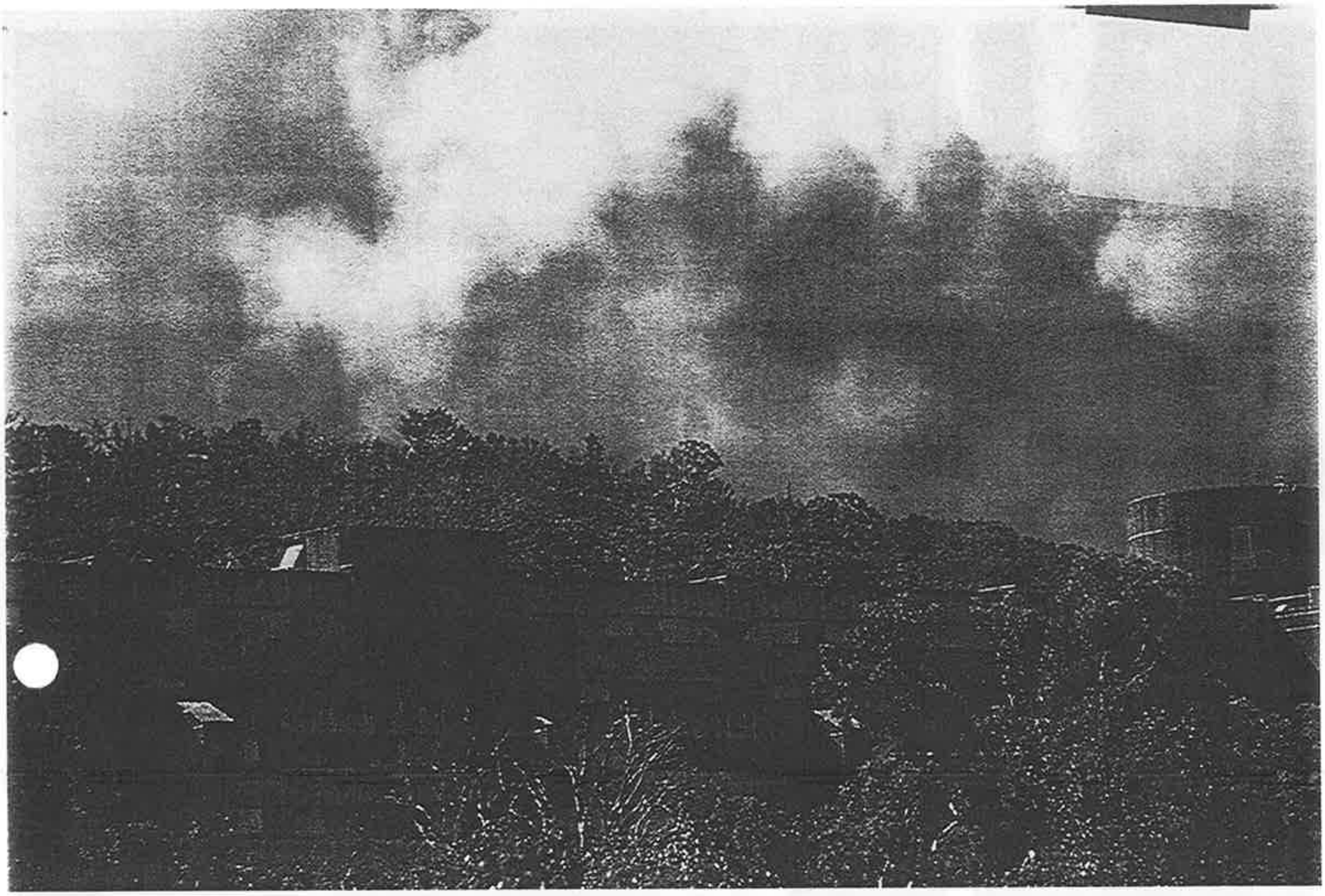


Australia is famed for its fires, which destroy property, wildlife and people. Ecologists have turned arsonists to fight them

Fire in the bush

Australian bush fires challenge environmental scientists to find a way of controlling forest fires. It turns out that the Aborigines had the answers

Bob Vines

EARLY in 1987, bushfires raging around Sydney in New South Wales made television news across the world. Australia is famed for the ferocity of its bushfires, and the southeastern part of the continent shares, with California, the dubious reputation of having the worst rural fires in the world. Recurring drought and the flammable nature of the eucalyptus trees can lead to awesome fires in heat waves. Only four years ago, the disastrous "Ash Wednesday" fires of 16 February 1983 in Victoria and South Australia produced damage estimated at A$500 million. The great forest fires of January 1939 in Victoria were even more devastating. They killed more than 70 people, and destroyed almost 1·45 million hectares of forest, which lowers income from timber even today.

These outbreaks happened during severe droughts. But fires can also occur in the semiarid regions of Australia. In the dry inland areas, which are usually sparsely covered, rain encourages plants to grow. In the summer of 1973-74, much of the country experienced heavy rain. The resulting exceptional growth led, in the following dry season, to bushfires in all mainland states except Victoria, where fires raged only in a region of 10 000 hectares in northern Mallee (an infertile plain that supports eucalyptuses and little else). In 1974-75 1.25 million square kilometres were burnt—one-sixth of the entire continent! Most of the fires were in such remote regions, however, that most people were unaware of the widespread damage.

Fires can be appallingly destructive. Animals are killed, people are burnt to death, houses are razed to the ground and other property is irreparably damaged. In the US, the forest fires of 1871 around the town of Peshtigo in Wisconsin killed 1500 people. Serious fires in Michigan, Minnesota and the adjoining Canadian provinces brought widespread destruction at the same time.

How can such fires—which, after all, are natural phenomena—be controlled? Long before white settlers reached Australia, human beings had made their mark on the continent. The Aborigines used fire as a tool, for both hunting and ceremonial purposes. And, it now seems, the Aborigines' way of dealing with fire has a lot to teach modern Australians.

Aborigines probably came to Australia between 40 000 and 50 000 years ago, perhaps even earlier. Pollen in cores drilled from different parts of the continent shows that the vegetation changed at about that time. The interpretation of this evidence is controversial, but the fires of the Aborigines may have caused this sudden change in the character of forests.

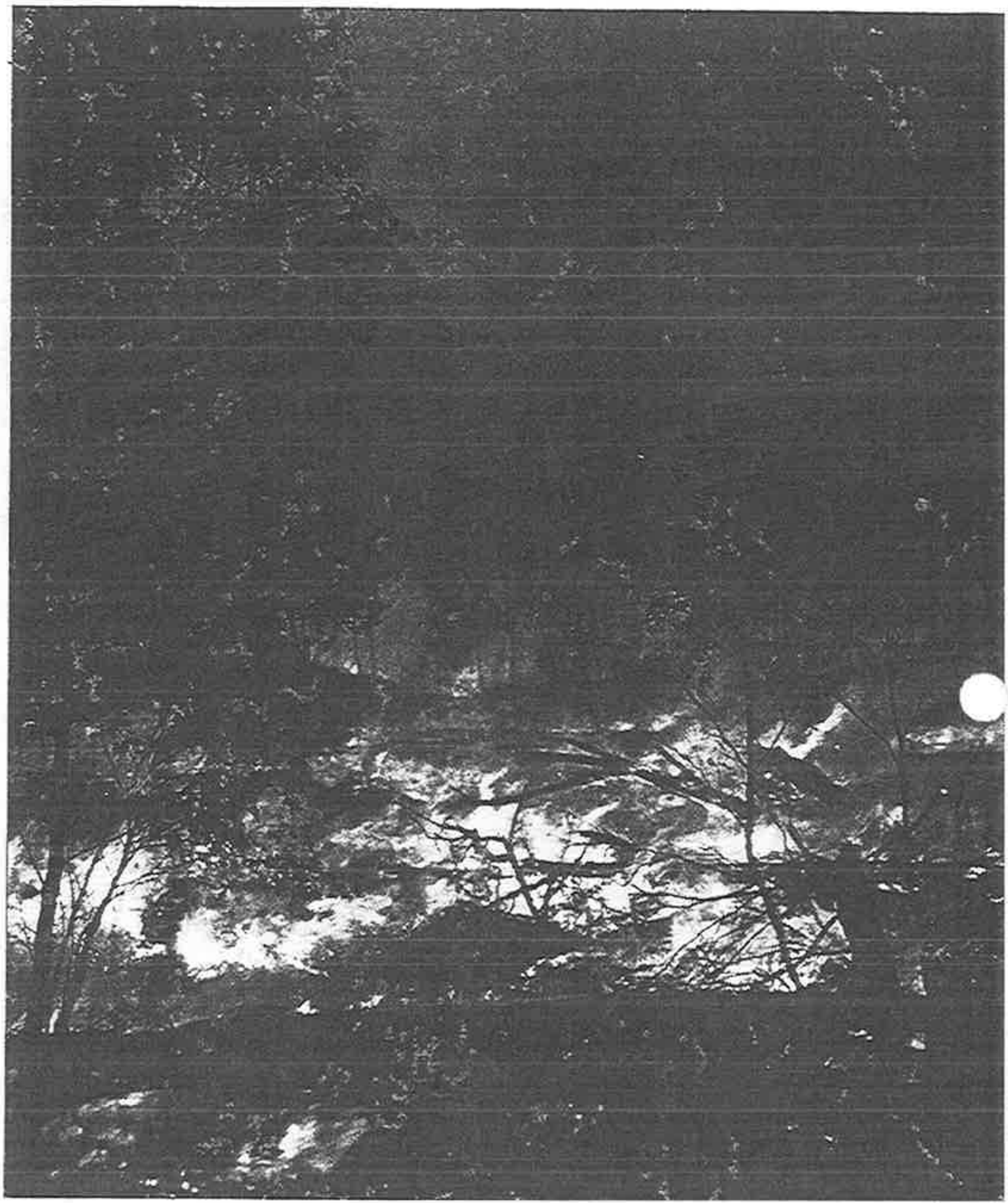
No one doubts that the natives used fire. Researchers increasingly appreciate the "technology" developed by Aborigines living in harmony with a harsh environment. But even in 1848, Major Thomas Mitchell, Surveyor General of New South Wales, recorded how the natives were "superior in penetration and judgment to the white men composing my

Photos by R. Vines Australian News

Eucalyptus makes most wood burn like dry fuel

C. M. Perrins/OSF

Forest litter builds up rapidly



At the height of a bush fire, flames can climb into the crowns of trees

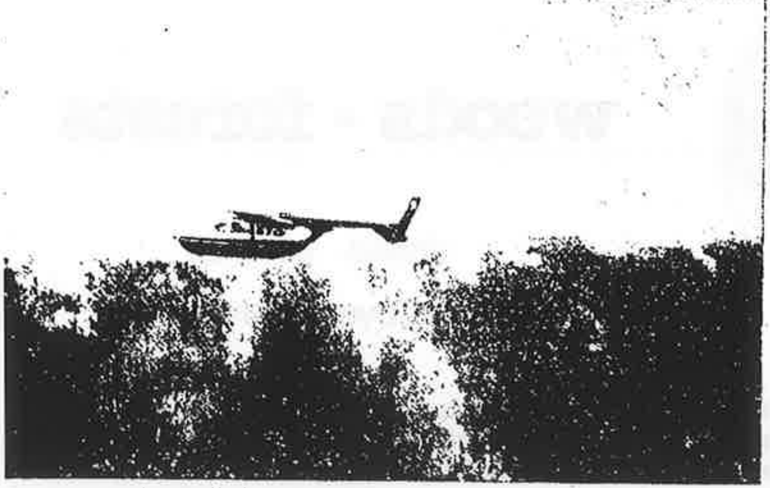
party. Their means of subsistence and their habits are both extremely simple; but they are adjusted with admirable fitness in the few resources afforded by such a country." He went on to draw particular attention to their use of fire. The Aborigines created open country in which kangaroos proliferated, burnt long grass to expose small animals on which they fed, and created the right conditions for food plants to grow. "But for this simple process, the Australian woods had probably contained as thick a jungle as those of New Zealand or America, instead of the open forest in which the white men now find grass for their cattle."

The advent of the white settlers, however, changed the balance once again. Following European tradition, they saw fire as an evil to be stamped out, as quickly as possible. By the early 20th century, they had decreased the area burnt each year. Inevitably, both living trees and dead combustible material began to build up. So when fires did occur, they were more concentrated and violent than anything that had been seen on the continent for thousands of years. A new era was born.

In the 1950s, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) appointed A. R. King to investigate the growing problem of bush fires. He was responsible for pioneering work on protection of fire fighters. The fire shelters used by the US Forest Service today are based on a design for a bush fire-survival tent that he developed in the early 1960s. From an extensive study early Australian journals, King concluded that practices since colonisation "had produced more severe and damaging bush fires" than in the days before the white settlers arrived. So how could we control modern fires?

A. G. McArthur, the "father" of Australian research on bushfires, studied experimental fires lit under different conditions. He could then relate some of the variables—the moisture and quantity of the fuel and slope of terrain—to the kind of fire produced. Thus researchers could begin to determine in advance the rate at which fires intentionally lit to clear forests would spread. With this aid, foresters could clear countryside by hand lighting—a return to the practices of the Aborigines before the arrival of white settlers. Now, however, we can go one better than the natives.

Research has continued, within the CSIRO, to find out more about bushfires and how to control them. This has led to some surprising insights. For example,. we had assumed that water cooled the flames mainly by extracting heat as it evaporated. Yet water is far more effective at "damping down" a fire than this effect alone can explain. It now seems that damp fuel is less flammable because water decreases the rate of burning, which reduces the intensity of the fire and promotes partial combustion of the fuel, which in turn makes more smoke and lessens the amount of radiant heating from the flames. So unburnt fuel ahead of the fire has less chance



Controlled burning helps to prevent devastating fires

Incendiaries dropped from aeroplanes burn 2 hectares in a day

to dry out before the flames reach it. On the other hand, oils and waxes in the leaves of eucalyptuses produce the opposite effect. They do not significantly increase the amount of heat the fire produces, but encourage rapid burning, which makes most wood behave more like dry fuel.

Scientists also studied the way that heat is transferred through the bark of a tree, using thermocouples placed just under the bark. Resistance to fire, we discovered, depends much more on the thickness of the bark than its moisture content, and only large trees with thick bark can survive severe fires. Even small trees, however, are usually undamaged by planned burning, because the flames never become hot enough to damage the living cells below the bark.

Researchers measured the temperature of the flames themselves indirectly. Objects surrounded by flame can experience radiation of intensities greater than 100 kilowatts per square metre (kW/m^2). Fire fighters 2 metres away from a line of flame 1 metre high encounter heat radiation of 2 kW/m^2 which is painful to exposed skin after 30 seconds. Major "wild" fires, like the ones of Ash Wednesday 1983, produce 50 000 to 70 000 kW per metre of fire front, with a typical output of heat as high as 100 000 megawatts per mile (the equivalent of 100 million single-bar electric fires). In disasters, fires may be many kilometres long. How to control them? Prevention, rather than control, is the only option. But we had to make sure that controlled burning would not get out of hand, and be worse than the disease it was supposed to cure.

We needed to know how small fires develop into large wild fires, and began to tackle the problem in the late 1960s in a series of experiments. There are two types of damaging wild fire, one driven by strong winds (like the Ash Wednesday outbreaks) and the other fed by its own heat, which produces, through convection, columns of smoke more than 6 kilometres high, as air is sucked in from all sides to fuel the fire. Nobody would start controlled burning when strong winds were likely. But we had to understand convective burning to prevent our controlled fires running away.

We decided to study such conflagrations by deliberately lighting fires, with the help of the forests department of Western Australia. Foresters dropped small incendiaries from the air, to start fires when the weather discouraged the development of a major bushfire. Our sites contained about 50 000 tonnes of potential fuel, spread over about 3000 hectares in each of the three tests, which could burn at the rate of 30 000 tonnes of fuel per hour. Researchers monitored the fires on the ground and from aircraft flying through the smoke columns.

In each of the three tests, air flowed from all sides into the convection column: more than 400 cubic kilometres of air each time (by inflow, turbulent mixing and the effect of prevailing winds). As water vapour carried aloft condensed, clouds formed. More than a million tonnes of water condensed out of high altitude in each of the experiments.

In the largest fire, the column of smoke rose to more than 4 kilometres. All the condensing water vapour increased the convection as it gave up latent heat to the column. This probably contributed the equivalent of burning an additional 40 000 tonnes of fuel—that is, doubling the convective powers of the fire.

The only way to control such fires is to reduce the amount of fuel available—all other factors are outside human control. Our research helped to established criteria for doing this safely, by burning. The intensity of a fire is roughly proportional to the square of the fuel quantity—increase fuel by a factor of 10 and you increase the intensity of the fire by a factor of 100. The best, and cheapest, way to control the amount of fuel available is by burning the bush intentionally in spring or autumn, when the conditions are right to produce mild fires that will not get out of hand.

So ecologists came back to the Aboriginal technique, but upgraded to take advantage of modern technology. Light aircraft carrying small incendiary capsules, costing only a few cents each, set light to forest in predetermined spots, which form a grid pattern over a wide area. Foresters space the capsules according to the prevailing conditions, so the fires develop slowly and burn gently throughout the day. The same fires link up only in the cool of the evening, and as they run into each other they extinguish themselves. The technique is extremely versatile: on hotter or more windy days, moister sections of forest are burned. On cooler days the drier, open areas, or ridge tops, are treated. The aim is to produce a fire that behaves consistently from day to day.

D. R. Packham, of the CSIRO's team, developed the method of lighting fires from aircraft. It is now routine, especially in Western Australia. Mobile radio beacons guide the aircraft on the desired flight paths, and a semiautomatic machine ejects incendaries at suitable intervals. A single aircraft can burn up to 250 square kilometres each day when the conditions are suitable.

Scientists in other parts of the world have also studied large-scale fires. The US Forest Service, for example, has changed its practices dramatically in the past 20 to 25 years. Planned burning is no longer suspect, and in somes cases the US Forest Service has adopted "let burn" policies for fires started by lightning strikes or other natural causes. This approach has, however, not yet been universally adopted. In Thailand, for example, it is still official policy to prevent fires, because of the risk to wildlife. This policy has been questioned by researchers who point out that, as a result, when fires do break out they are likely to be very intense, because of the build-up of combustible material (*Nature*, vol 325, p 486). Perhaps other countries can still learn from the Australian experience. □

Robert G. Vines was in charge of the CSIRO Bush Fire Research Section from 1965 to 1974.

Nov. '87
Update

woods & forests

Research Note 101

Weed control for native plants

Weeds look unsightly in ornamental plantings but the main benefit from controlling them in any situation is in the conservation of soil water and nutrients for the growth of seedlings. The photos below show the growth constrast of seedlings after one year with and without weed control.


with weed control


without weed control

This research note covers the weed control techniques, including herbicides that have been used with success when establishing seedlings in Woods and Forests' *trial work.

Weed control timing, area to treat, length of control and other aspects on establishing seedlings can be found in Fact Sheet No. 8, "Broadacre Establishment Techniques".

*The Minister of Forests accepts no liability for the use of these trial results in other situations.

Think of weed control in two phases. Firstly, killing existing weeds and secondly, preventing further weeds becoming established. Just killing the weeds before planting is usually not enough, because in most situations weeds will quickly invade the cleared area. Repeated cultivation, or the repeated use of knockdown herbicides can be used to keep the area weed free. Alternatively, research has shown that ONE application of soil-residual herbicides can keep the area weed free for many months. The technique to use depends on what suits you, but the important thing to do is KEEP THE AREA WEED FREE.

Cultivation

Cultivation is most useful when it is done prior to planting as a part of paddock 'working' or when the rhizomes of perrenial grasses are to be exposed so that they dry out. Also, most soil-residual herbicies work better when they are applied to a cultivated soil, rather than one with large clods of soil and lots of organic matter. However, cultivation brings weed seeds to the surface, it turns in dead weeds and causes the loss of the mulch effect, it can damage the shallow roots of native plant seedlings and is a lot of work if it has to be done by hand in among seedlings.

Knockdown Herbicides

Existing weeds can be killed using a knockdown herbicide (e.g. glyphosate, diquat, paraquat) either prior to planting, after planting but with seedling protection or after planting without protection when the herbicide is selective (e.g. Fusilade® and Sertin® are selective for grass control). Weeds knocked down after they have grown taller than 5 centimetres are sometimes effective as a mulch that limits further weed seed germination. However, repeated use of knockdown herbicides generally is required to prevent further weeds becoming established. This can be avoided with the use of a soil-residual herbicide.

Label rates for knockdown herbicides should be followed. Some knockdown herbicides have residual effect that damages seedlings but those mentioned above have not been found to act in this way.

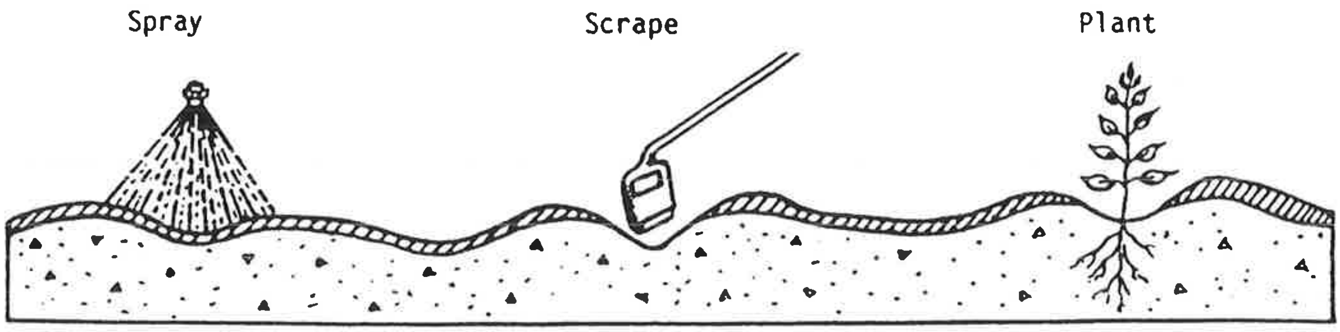
Soil-residual Herbicides

Soil-residual herbicides generally do not have a knockdown effect, but they keep the soil weed free once the existing weeds have been killed with a knockdown herbicide, or by cultivation. There are several methods in which soil-residual herbicides are being used.

A. Spraying Before Planting

1. Spray/Plant
The residual herbicide is applied to the soil before planting. In a lot of cases the residual herbicide can be mixed with a knockdown herbicide so that only one spraying operation has to be done. (see mixing guide - page 5)

2. Spray/Scrape/Plant
This is the same as 1. except herbicide contaminated soil is scraped away from the area where the seedling is to be planted. Herbicides that have to be treated in this way have sometimes damaged seedlings when not scraped away. The contaminated soil has fallen down the planting hole and the herbicide has been taken up by the roots of the seedlings. These herbicides have been used with safety when a 2-3 centimetre depth of soil is removed from an area 15 centimetres x 15 centimetres. It can be done with hand tools or tractor mounted equipment that throws a sufficient area of contaminated soil away from the planting zone.



B. Spraying After Planting

1. Plant/Spray
After the existing weeds are killed and the seedlings planted a residual herbicide is applied without protecting the seedling foliage from the residual spray.

2. Plant/Spray with Protection
Some residual herbicides will damage the seedlings if they contact the foliage. In these cases the methods of 1. (above) is used but seedlings must be covered with a bucket, a piece of P.V.C. pipe or something that ensures no herbicide spray contacts the foliage of the seedlings.

3. Plant/Spray with Protection with Knockdown Herbicide Included.
Sometimes it is convenient to kill the weeds and apply the residual herbicide in one spray after planting. In these cases the seedlings have to be protected from the spray unless both the knockdown and the residual herbicide will not harm the seedlings.

The following table lists soil residual herbicides, their rates and methods of use, that have been used with safety on a range of shrubs and trees in research trials and planting projects.

	Weeds Controlled		Rate (Product per hectare)			Methods Used			
	grasses	broad-leaves	sand	loam	clay	Pre-planting	Pre-planting with scrape	Post-planting	Post-planting with protect
Surflan® (500g/L oryzalin)	yes	few	4.5-5.0 L	5.0-5.5 L	5.0-6.0 L	S	N	S	N
Goal® (240g/L oxyfluorfen)	some	yes	4-5 L	4-6 L	4-6 L	S	N	D	S
Kerb® (500g/L propazamide)	yes	few	1.5-2.0 kg	2.0-2.5 kg	2.0-3.0 kg	S	N	S	N
Gesamil® (500g/L propazine)	many	many	1.2-1.6 kg	1.5-3.0 kg	2.0-4.0 kg	D	S	n.a.	n.a.
			0.9 kg	1.5 kg	2.0 kg	n.a.	n.a.	S	N
Gesatop® (500g/L simazine)	most	yes	1.0-1.6 L	1.4-3.0 L	2.0-4.0 L	D	S	n.a.	n.a.
			0.7 L	1.4 L	2.0 L	n.a.	n.a.	S	N

Key to the particular herbicide and method combinations.
S = Successfully used in research trials.
N = Successfully used, but not found neccessary.
D = Damage has resulted.
n.a. = Not applicable.

Weeds Controlled

- Broadleaves

Specific weed spectrums are detailed on labels, but generally, of those listed, the herbicides most successful in controlling broad leaf weeds are Gesatop®, Gesamil® and Goal®. Gesatop® is cheaper than Gesamil® which is cheaper than Goal®. However Goal® is safer than Gesamil® which is slightly safer Gesatop®. In other words, the safest chemical is the most costly! However the rates listed in the table have been used with safety, so when a smaller safety margin can be put up with in order to save dollars, Gesatop® or Gesamil® is used, but where a larger degree of safety is required then Goal® is used.

- Grasses

In some situations Gesatop® and Gesamil® will control the grasses as well as the broad leaves, but in heavy grass infestations or when applied early in the season (eg: May-July) then usually Surflan® or Kerb® has to be added for complete grass control. Surflan® and Kerb® have also been used for complementing the weed spectrum of Goal®.

More on mixing herbicides is given on page 5.

Notes on the Herbicides

1. Gesatop® and Gesamil®
   If either of these two herbicides are used prior to planting then the scrape technique has to be used. If used after planting lower rates are tolerated by the seedlings because the chemical is on the ground immediately above the root system of the seeding. (Callitris species have shown marked tolerance to these two herbicides)

   On sandy soils the rates found to be safe for post-planting overspraying have been marginal for weed control, but the rates safe for the scrape technique are higher and give better weed control. However for all soils the higher rates within the range for the scrape technique have not been tested yet for their safety in high rainfall areas, water logged areas, other situations where a lot of herbicide leaching is expected, or on highly alkaline sites

2. Goal®
   Goal® in particular has given best weed control when applied to a cultivated or trash free soil. For this reason it performs best when the weeds are killed about 5 weeks before applying Goal®. Goal® will kill most young seedlings that may come up in this 5 weeks. Also Goal® does a better job when applied in cooler weather. While Goal® applied before planting has been safe in trial work, excessive soil disturbance at planting can destroy the Goal® barrier and allow weeds to escape. It has been used most as a post-planting spray, without contacting the seedling foliage.

3. Surflan® and Kerb®
   These two herbicides primarily control grasses and it is probably for this reason that they have shown a high degree of safety with native plants.

4. Other Residual Herbicides
   There has been several reports of successful seedling establishment using trifluralin (eg: Treflan®), but it can only be used where mechanical incorporation prior to planting is possible.

Atrazine (eg: Gesaprim®) and products which include atrazine in them (eg: Vorox AA®) have sometimes been used with the scrape technique without damaging seedlings, but there have been many cases when seedling damage has resulted.

Mixing Herbicides

As well as mixing residual herbicides to improve the weed spectrum controlled, it is sometimes advantageous to apply soil-residual and knockdown herbicides in the same spray operation. The following table summarizes the compatability information of the soil residual herbicides mentioned above; with each other and with some knockdown herbicides.

		Residual					Knockdown	
		Oryzalin	Oxyfluorfen	Propazamide	Propazine	Simazine	Glyphosate (e.g. Roundup)	Paraquat
atrazine	"Gesaprim®"	NT	NA	NT	NA	NA	*L	NT
oryzalin	"Surflan®"	.	L	S	S	L	L	L
oxyfluorfen	"Goal®"	.	.	S	NA	NA	L	L
propazamide	"Kerb®"	.	.	.	S	S	S	NT
propazine	"Gesamil®"	.	.	.	.	NA	S	NT
simazine	"Gesatop®"	.	.	.	.	.	*L	L

KEY

L = labels support mixing
S = successfully used in research trials
NT = not tested
NA = no application likely for this combination

*Monsanto recommend to mix crystalline ammonium sulphate at 2 kilograms per 100 L of spray solution when using this combination; only necessary with simazine if using less than 3 L per hectare of Roundup® (glyphosate).

Mixed herbicides need to be used with a technique that suits both herbicides. For example, Surflan® can be used without seedling protection, but if mixed with Goal® protection is needed.

When mixing soil residual herbicides is appropriate, label information indicates that dry flowables and wettable powders should be added to the water in the tank first and agitated until they are completely dispersed. Next to be added are solution products and emulsifiable concentrates last.

Label recommendations for mixing knockdown and residual herbicides usually follow the order of -

1. Fill the spray tank 1/3 to 1/2 full with water and start agitation.
2. If crystaline ammonium sulphate is to be added, wash it through a mesh screen into the tank and mix thoroughly.
3. Add the residual herbicide and mix thoroughly.
4. Add the knockdown and mix thoroughly.
5. Maintain agitation and use the mixture promptly.

Check label instructions for all chemicals.

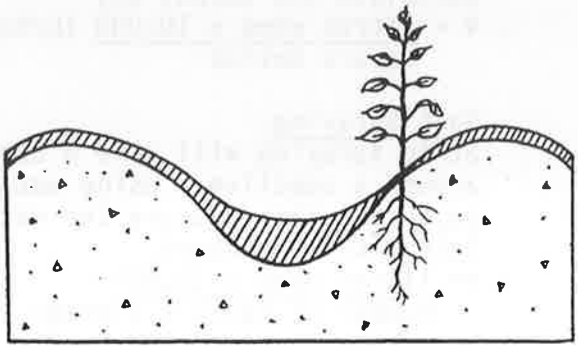
Incorporation

All of the soil-residual herbicides mentioned above (except oxyfluorfen) require rainfall incorporation. For this reason, their use has been restricted to the rainy season, except where irrigation has been used to incorporate them (e.g. water winch, sprinklers).

Oxyfluorfen only needs to be applied to bare damp soil, which also can be achieved with irrigation if rainfall is inadequate.

Herbicides in Depressions

When seedlings are planted in the bottom of a basin rip-line or other depression there is a chance that herbicides leaching to the lowest point will damage them. When this leaching is suspected (i.e. high rainfall, very sandy soils) seedlings are planted on the side of the basin or the 'hill' of the rip-line (as illustrated opposite) or any higher ground.



Examples

The following are examples of how the herbicides mentioned above have been used.

1. 1,500 trees, mainly Eucalyptus species but some Acacia, Callitris and Casuarina species were planted in a sandy loam in a 450 mm rainfall area. Planting was done in autumn. Existing weeds were knocked down with Gramoxone® and Reglone® at label rates, seedlings were planted on the 'hill' of rip-lines and sprayed without protection with Surflan® at 5.5 L/ha plus Gesamil® at 1.5 kg/ha using a knapsack.

2. 100 Eucalyptus camaldulensis were planted on a sand over clay soil in a 450 mm/annum rainfall zone. Existing weeds were killed by cultivation, seedings were planted, and, with seedling protection, Goal® at 4L/ha plus Kerb® at 2kg/ha were applied to the soil.

3. A mixture of species were planted on a sandy loam in spring. Roundup® (label rates) and Gesatop® at 2L/ha were sprayed, scraping was done, and seedlings planted.

Perennial Weeds

Areas with perennial weeds have been treated prior to seedling planting to reduce the weed pressure. Cultivation or translocated herbicides (e.g. glyphosate) can be used, and sometimes need to be done the previous season as well as just prior to planting. Growth of perennial weeds after planting either has to be accepted, or spot-sprayed using seedling protection or blanket sprayed if it is susceptible to the selective grass herbicides (e.g. Fusilade®, Sertin®).

Equipment

The scale of the job and resources available determines whether vehicle mounted equipment (i.e. rippers, spray tanks) or hand equipment (i.e. mattocks, knapsacks) are most suitable. Help for calibrating boom sprayers is found in Department of Agriculture fact sheets: No. 10/86 "Setting up a boom sprayer". No. 11/86 "Boom sprayer cleaning, maintenance and calibration". The following notes offer some help for knapsack calibration for soil-residual herbicides.

The two things to work out are the (1) the volume of water you knapsack puts out over a certain area and (2) the amount of chemical to put in your knapsack.

1. Volume of water over a certain area (V L/ha)

   Strip Spaying

   Using water only in the knapsack spray into a container for a given time e.g. two minutes. Measure the volume in litres. Then spray a strip of ground for the same period of time and measure the area (length by breath) in square metres.
   Calculate the output as,
   $$V = \frac{\text{litres used} \times 10{,}000}{\text{square metres}} \text{ (L/ha)}$$

   Spot Spraying
   Strip spraying will give a totally different result than walking in a circle around a seedling. Using water in the knapsack spray a number of spots (e.g. 20) then measure the water used and the average area of the spots.
   Calculate the output.
   $$V = \frac{\text{litres used} \times 10{,}000}{\text{number of spots} \times \text{average area of spots (L/ha)}}$$

   A water output of at least 200 L/ha is needed for most soil residual herbicides. Certain things will affect the water output and a calibration has to be done when any of them is changed. They include;
   - Nozzle type with different output.
   - The height you hold the nozzle, which affects the width of the spray, which affects the area you are covering.
   - Your walking speed. It is best to calibrate at a walking speed you are comfortable with.
   - The operating pressure. Some knapsacks have pressure gauges, but the important thing is that it is kept relatively constant.

2. Amount of Chemical

   The amount of chemical to put in a knapsack is calculated by using the formula,
   $$\text{Amount} = \frac{\text{Rate/hectare} \times \text{capacity of knapsack}}{\text{V (the L/ha you calculated)}}$$

   Example

   You used 1.65 litres spraying 20 spots of 3 m^2 area, and you want to use Gesatop® at 1.5 L/ha. Your knapsack holds 15 litres.
   $$V = \frac{1.65}{20 \times 3} \times 10{,}000 = 275 \text{ L/ha}$$
   $$\text{Amount/knapsack} = \frac{1.5 \times 15}{275}$$
   = 0.082 litres
   = 82 millilitres Gesatop® for each 15 L knapsack

It cannot be over-emphasised that calibration must be done for each particular knapsack, with a particular nozzle, for one operator, using one spraying system (i.e. spraying in a straight pass or in circles as you walk around a tree). These variables affect the chemical output many times over. Improper calibration will lead to either ineffective weed control or over-application and tree death.

For more information contact the Native Plant Section, Murray Bridge, South Australia, telephone (085) 32.3344.

The Native Plant Section provides the following services:

- Rural Tree Scheme - applications from April to October each year for seedling supply in the following autumn or spring. Attractive discounts apply.
- Farm tree plans. Landscaping plans and contracts.
- Contract tree planting for woodlots, windbreaks, shelter belts, shade, salinity amelioration and effluent disposal.
- Direct seeding contracts using native species mix or lucerne tree.

Native plants and information on species to suit individual needs are available from Woods and Forests Native Plant Sales Outlets at -

Murray Bridge	Native Plant Section, Bremer Road, Murray Bridge Open 7.30 a.m. to 4.30 p.m. weekdays Telephone (085) 32.3344
Belair	Inside Belair Recreation Park, adjacent Old Government House Open 7 days, 8.00 a.m. to 4.00 p.m. weekdays and 10.00 a.m. to 4.00 p.m. weekends Telephone (08) 278.7777
Cavan	Corner of Diagonal and Goldsbrough Roads, Cavan Open 8.00 a.m. - 5.00 p.m. weekdays and 8.30 a.m. to noon Saturday Telephone (08) 262.6509
Berri	Worman Street, Berri Open 10.00 a.m. to 4.00 p.m. weekdays Telephone (085) 82.1599
Bundaleer	Bundaleer Forest Reserve, 9 km south of Jamestown Open from May to October between 1.00 p.m. to 4.00 p.m., Tuesday to Friday Telephone (086) 65.4044

Chip 'n' bark mulch and other products are also available at some of the above outlets.

FIRE AND REGENERATION

Thanks to Ian Higgins for contributing the following article.

Rediscovering firestick 'farming' - Regeneration of indigenous plantscapes with native grasses

by Ian Higgins
38 Main Road, Campbells Creek, Victoria 3450

Control of the ground layer is vital in any revegetation work. The ground layer is where recruitment of both weeds and native plants takes place. If management can tip the balance of recruitment in favour of the natives, we could win a few battles in the fight to conserve viable native vegetation. The experiences described below show that local native grasses and fire can be used to gain control of the ground layer. Once weeds are reduced, regeneration of a range of other species becomes possible.

John Robinson lives at Strathfieldsaye, near Bendigo (rainfall 550 mm. p.a., elevation 220 m.) on the silty soils next to Sheep Wash Creek. His interest in wildlife and native vegetation has led him to work at increasing the extent of the remnant native grasses that were patchily present amongst the weeds. The grass species are mainly *Danthonia linkii*, and *D. racemosa*, with some *D. procera*, *D. duttoniana*, and *D. eriantha*. *Elymus scabrus*, *Microlaena stipoides*, *Stipa scabra ssp. falcata*, *S. mollis*, *Aristida behriana*, and *Themeda triandra* are also present. There are very few broadleaf herbs and few species. They included *Pelargonium rodneyanum*, *Rumex brownii*, *Alternanthera denticulata* (and a so far unidentified *Alternanthera*) and locally rare *Glycine tabacina* and *Desmodium varians.*

The five acres have been John's house block for twenty years and are now a marked contrast to the adjacent paddocks. The ground layer vegetation there, like most of the district, is dominated by annual weeds (Wild Oat, Bromes, Barley Grass, Silver Grass, Capeweed etc.) Away from the trees perennial weeds (Docks) and exotic pasture species (*Phalaris*) occur. In this situation, which is widespread in much of rural Victoria, there is very little regeneration of any native vegetation, including trees.

Previously John hand weeded amongst some of his native grass patches and this has allowed the stands of grass to thicken up. Now he is able to sweep up the fallen *Danthonia* seed (uncontaminated by weed seed) and use it to sow new areas.

Recently, he has started using fire to achieve weed control. He feels that autumn or summer fires are of no disadvantage to annual exotic weeds and burning at these times simply maintains the status quo.

By burning in spring (the fuel load is provided by the previous season's ungrazed growth) he has found that the balance is tipped in favour of the native (perennial) grasses which recover well from (and seem rejuvenated by) fire even when quite small plants. Burning at this time retards and often destroys the annuals present, reducing their seed set. It also helps remove the layer of partly decomposed plant residues (grass and tree leaves) and exposes mineral soil.

John emphasises that this litter layer is of great importance as its presence seems to favour and support the growth of annual weeds and preclude the regeneration of native species. He rakes up any unburnt litter into heaps for burning later.

Burning in this manner has allowed the native grasses to regrow and produce a seed crop, and new seedlings colonise the bare soil.

Tree and shrub seedlings also find ample opportunities to regenerate, although the next year's burning will kill or cut them back. If applied on a broad scale, this regime would create an open grassy landscape just as Aboriginal firing practices are said to have. When John wants the seedlings to survive, he avoids burning them in the next year.

The point is that there are plenty of seedlings regenerating. (Perhaps herbaceous ground flora species could be re-established the same way?)

John's experiences show that burning can help rejuvenate remnant vegetation. Does this mean we have our rural revegetation (tree planting) priorities arse about? Perhaps if we focussed on managing the vegetation at ground level, the re-establishment of trees would take care of itself (given a seed source).

* * *

REVEGETATION OF WALLABY GRASSES

The following article is one of a series of native grass revegetation information sheets produced by Bushland Flora, P.O. Box 312, Mt. Evelyn, Victoria 3796. It is reprinted with permission.

REVEGETATION OF WALLABY GRASSES (*Danthonia* spp.)

Introduction

These guidelines have been prepared to help in the establishment of Wallaby Grasses (*Danthonia* species) from seed supplied by Bushland Flora.

Site Selection

There are two important aspects of site selection:

1. The site must be completely weed free. Wallaby Grasses are not as vigorous as most exotic grasses and herbs and will bot be able to establish if they have to compete with them. Sites which are poor in nutrients, with low moisture levels (like under trees), sunny north-facing, and few existing weeds, are best suited to Wallaby grasses.

2. The site must not be invaded by weeds within three to four months. Wallaby Grasses are slow to establish and if the site is initially weed free, but weed seeds germinate within three to four months then it is likely that the young Wallaby Grass seedlings will be smothered.

For these reasons we recommend Wallaby grasses be sown only onto virgin subsoil which is free of weed seeds, or that extensive site preparation works are undertaken to eliminate all weeds and weed seeds.

Wallaby Grasses are suited only to low wear situations, and do not tolerate large amounts of foot or vehicle traffic.

Seedbed Preparation

Sites which contain weeds should be sprayed (when the weeds are actively growing) with "Roundup" (Glyphosate) several times at three to four week intervals to kill existing growth and subsequent weed regrowth.

The seedbed for lawns needs to be properly prepared for best results, including rotary hoeing and raking. For sites such as embankments it is best to scarify the soil surface to enable the seed to get a good hold into the soil, but rotary hoeing is normally impossible.

Sowing

Wallaby Grasses require cool temperatures and high moisture levels for germination, and must be well established to survive the first Summer. For these reasons we recommend sowing in autumn (March onwards), after the first major rains, or Winter (up to the end of July). These times enable the seeds to germinate well, and give the seedlings enough time to establish before their first Summer.

If irrigation is available then Wallaby Grasses can be sown at almost any time of the year. Spring sowing is good if irrigation is available as Wallaby Grasses respond well to irrigation over Summer.

If the seed is supplied as "florets" which are the individual fluffy fruits (creamy and very hairy), then these need to be sown on the surface by hand, or applied by hydro-mulching or hydro-seeding. Hand sowing is difficult to get even, so we recommend you sow 45% in one direction, and sow 45% in the opposite direction, and keep 10% to re-seed any bare patches which may become evident after germination. For hydro-mulching we recommend using 1650 Kg/Ha of cellulose fibre mulch, and on embankments 150L/Ha "Staybind" PVA binder should also be added. Hydro-seeding is where the seed is applied in water without the mulch or binder, and is suitable only for flat sites where moisture-stress is not likely to be a problem (the cellulose fibre mulch helps reduce moisture stress).

Pure seed (red-brown and about 1 mm diam) can be sown with equipment, but must be sown on the surface only. It is best to bulk-up pure seed with sand as it is very difficult to sow pure seed at a light enough rate.

We recommend and supply seed at a turf sowing rate of a minimum of 1000 germinable seeds per square metre, to result in a rate of 100 seedlings per square metre. For non turf areas we suggest that this rate can be reduced.

Establishment

Seed or florets sown in Autumn or Winter need no special attention during germination as long as moisture levels are high. If rains are unreliable supplementary watering must be conducted as most native grasses are more susceptible to moisture stress during germination than are exotic grasses.

Spring or Summer sowings require irrigation, and we recommend the seeds must be kept constantly moist until germination which can take 2 weeks, then daily for the next two weeks, and weekly waterings until the Autumn.

Once established Wallaby Grasses are very drought tolerant, and watering in Summer is not necessary. However to keep them green, especially in a lawn situation, watering over Summer is recommended. They respond well to Summer irrigation, unlike many exotic grasses.

Weeds should be spot sprayed with "Roundup" or hand weeded until the seedlings pass a 5 leaf stage. After this broad-leaf weeds can be selectively eradicated by using a herbicide containing MCPA and Dicamba (e.g. "Banvel M" or "Valiant"). Exotic perennial grasses will still require hand weeding or spot-spraying with "Roundup".

Management

For lawn situations Wallaby Grass can be mown to conventional heights, but is best if mown no less than 2 cm. For most situations Wallaby Grasses can be left unmown or only be cut a couple of times a year to remove the flowering or seeding heads (if desired), as the plants only grow 10-15 cm tall. The seed-heads are quite ornamental, being creamy coloured and very fluffy. Wallaby Grass forms a different lawn to conventional lawns because its foliage is often very fine and grey-green.

Wallaby Grasses are best not fertilised, as they can be short lived on fertile sites. They are particularly good on sites which are poor in Phosphorous.

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Direct seeding

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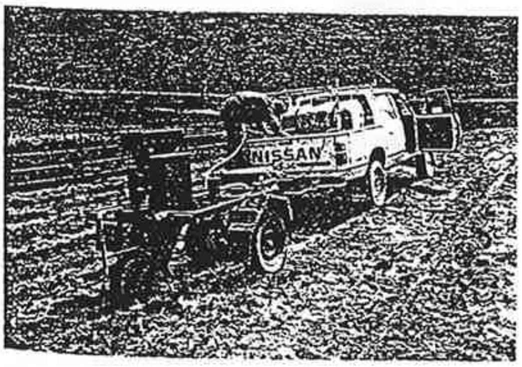
Introduction

There has been much progress in our understanding of suitable methods of direct seeding of trees and shrubs in recent years The concept of direct seeding is certainly not new, as it has been extensively practised in western Victoria since the 1870s, with many *Eucalyptus cladocalyx* (sugar gum) shelterbelts being established. There are many people and organisations in Victoria refining direct seeding methods suitable for both very localised areas and wider regions

Direct seeding of trees onto appropriately prepared ground can be a cost effective method of revegetating large areas. Direct seeding may be a useful method if plant spacing is not critical, or if thinning of stands will be undertaken (e.g. for timber production) Other tree establishment methods may be more suitable if trees are required at set spacings, seed is expensive or in short supply, or if seed is difficult to germinate.

Successful establishment is largely determined by climatic conditions, soil properties and competition between young seedlings and weeds. Direct seeding is a reasonably reliable method of tree establishment in areas with a stable, moderate environment. In more variable or extreme environments (e.g. areas with erratic seasonal rainfall, steep slopes) direct seeding can be uncertain, thus reducing its potential as a method of plant establishment


This site was sprayed with herbicide before seeding. Bituminous spray was applied with sowing.

(D. Race)

Direct seeding allows a random mixture of trees and shrubs to be established to provide a more complete barrier against harsh weather. When seed is being sown in row designs, species can be mixed in a row or sown in single-species rows

It is important to correctly combine **site preparation**, **weed control** and **time of sowing** if direct seeding is to be most effective. Plans for spring and autumn sowing are described below.

Spring sowing (September–October)

Sowing in spring appears to be the most successful time in:

- high rainfall areas (i.e. > 600 mm)
- areas prone to waterlogging or frost
- areas of reliable spring rain, as the combination of moisture and temperature suits the germination of most tree seeds

Site preparation

The proposed planting lines should be deep ripped over the drier months, when the subsoil will shatter. Driving back with a tyre over the rip line will firm the topsoil to avoid erosion There is no value in deep ripping during the wetter months when the subsoil is wet

In areas susceptible to erosion, prepare the ground for sowing on the contour Making intermittent gaps, or backfilling soil in sowing lines, may also reduce water flow in the sowing lines, thereby reducing the risk of erosion and the loss of tree seed In erosion prone areas minimise the width of sprayed strips and delay site work (e g scalping) until the day of sowing

Weed control

Adequate pest and weed control is essential if direct seeding is to be successful A control program may, in some cases, need to begin germinate after one fall of rain. Atrazine has some knockdown effect on young weeds and may be the best choice if you have delayed spraying in the hope that early weeds would die without follow up rain. Spraying over the seedlings in autumn with these and several other chemicals greatly improves survival and growth rates; damage done to the trees by the chemical is far outweighed by the gains in weed control.

How do you control weeds that have "escaped" in early summer, as a result of poor initial control work? The answer depends on the weeds. If you do nothing you may lose all the trees, particularly if capeweed has grown vigorously; however, capeweed cannot be controlled without affecting trees to some degree. Minimise the problem by using a very narrow scalp strip and a residual herbicide *before* scalping and sowing. If the trees later become smothered by capeweed a knockdown (e.g. oxyfluorfen 2–4 L/ha; glyphosate 1 L/ha) overspray will release them. Most of the tree seedlings will be protected by the capeweed itself, and will survive. Oxyfluorfen and glyphosate may scorch the trees, but they mostly survive.

A selective herbicide such as fluazifop-p, which does little harm to trees or broad-leaved weeds, can be applied if control of grass is the main problem. A knockdown herbicide can also be used, using a shielded spray at low pressure and working along each side of the row of trees. Trees may tolerate some knockdown drift when older than about 4 months. Use a watering can to immediately rinse chemical off any tree that has been accidentally sprayed.

Mouldboard method

This method of site preparation, which involves ploughing the soil, requires no use of residual herbicides. This method is well suited to those who dislike using residual chemicals. It is also suitable for waterlogged soils that remain inundated for long periods. Growth on the mounds can be exceptional. On drier sites, or in dry springs, this method is not as good as sowing in scalped lines: the lines seem to retain the moisture better.

In early spring, after applying a knockdown herbicide to control difficult weeds such as sorrel and phalaris, use a 3-furrow plough on sprayed strips to turn the sod and bury the weed seeds. A mound can be formed, if required, by ploughing back onto the first mouldboard line. Sow seed by hand where the furrow lines meet. Weed control should be adequate for 15 months; if not, knockdown oversprays may be considered (see above). It is important that seed is sown immediately after ploughing.

A combination of cultivation and chemical weed control can also be effective, but it is expensive, and is only suggested for problem sites and perhaps for autumn–winter sowing. Cultivation needs to be carried out early enough for a large number of weed seeds to have time to germinate before spraying. Grasses should have reached early tillering and broadleaves should be at the rosette stage before spraying.

Weed problems in spring sowing can also be reduced by a light application of knockdown herbicide in the spring of the year before sowing, or the area may be burned in summer to reduce weed seed carryover. Caution is needed if erosion is a potential problem.

Slugs and red-legged earth mite can be a very severe problem in a mild wet spring and early summer. Wingless grasshoppers can be locally abundant in mid-summer and must also be controlled if the population is high.

Autumn sowing

Autumn sowing suits lower rainfall areas and drier sites in the higher rainfall areas.

Problems

The major problems associate with autumn sowing are:

- weed growth after sowing
- losses resulting from pests (e.g. slugs, red-legged earth mite, brown pasture loopers)
- low ground temperature
- inundation, especially in high rainfall areas.

Without adequate weed control autumn sowing is unlikely to succeed. Good tree seed germination is no guarantee of success if weeds are growing freely. Even with good weed control there has been little success with autumn sowing in the higher rainfall areas; the results have been only 1% of that obtained from spring sowing.

Weed control will need to begin in the spring before sowing, so that weeds do not set seed. Follow up measures, after autumn rains, are essential. For details of weed control methods see **Spring sowing**, above.

year is reduced by spray-topping with a knockdown chemical in the spring before seed heads develop.

This method involves working the topsoil so that it is of a fine tilth with no existing weed growth. Seed can then be applied by hand, casting seed evenly across the topsoil. Rain will wash much of the seed into suitable niches for germination. The mouldboard method differs in that the topsoil is inverted to bury the weed seed and prevent most weeds germinating. The tree seed can be applied by hand or spreader over the ploughed area.

Another problem in the drier areas is the **loss of seed to ants**; this loss can be very high and may require the treatment of the seed with an approved pesticide before sowing.

Sowing rates

There is no satisfactory general rule of thumb that will tell you how much seed should be sown. The amount of seed required to establish the desired number of trees/m is shown in the box below. The amount of seed required depends on:

- tree spacing
- seed viability
- environment.

Tree spacing

Aim for double the desired final density; any excess plants can be thinned to leave the most vigorous seedling, or transplanted to fill gaps.

Seed viability

This varies widely between species (see **Table 1** in **Chapter 28** for a guide to viable seeds/kg for a number of native species).

Viability of seed may also vary greatly within a species, particularly when immature seed has been collected. Some idea of this variability within species is given in **Table 1** below. Viability of small seeds other than those of acacias and other native legumes also declines sharply (often unpredictably) after storage for several years. See **Chapter 28** for information about storage conditions and **Chapter 29** for pre-sowing treatment.

The following is a simple way to determine the viability of the seed to be used.

- Use a small spoon to measure a sample of the seed and chaff mixture and put the same amount (0.1–1.0 g) on each of 2 or 3 pots of sand. Cover very lightly with sand from a sieve.
- Keep the sand damp by standing the pots in a shallow tray of water.
- Count seeds germinated in a month or more and average the results. Express the result as viable seeds per gram (if weighing facilities are available) or simply as viable seeds per spoon.

Environment

Satisfactory germination and establishment depends on seed bed, pest and climatic factors. All species require continuous moist surface conditions, some for at least 2 weeks (e.g. *Melaleuca* and *Callistemon*). Some species (e.g. *Eucalyptus pauciflora* and *E. alpina*) need low temperature stratification (i.e. moist-chilling) to allow prompt ger-mination (see **Chapter 29**). *Bursaria spinosa* appears to have a day length requirement as it germinates prolifically shortly after the day of least daylight. It is not suitable for direct seeding in spring. For other species, germination will not occur until soil temperatures warm to the particular level required. Germination will be very poor on saline soil; seedlings are more successfully planted there on mounds (see **Chapter 17**).

Only a small part of the viable seed sown will survive in the field after germination; the percentage varies widely (e.g. 0.2–20% for eucalypts), depending on species and seasonal conditions. This loss factor must be allowed for when calculating how much seed is needed to sow each section.

The amount of seed required (N) to give a specified number of established trees per metres (S) over a given distance in metres (D) is as follows.

$$N = \frac{S \times D \times 100}{\%VSS \times VS}$$

where N = number of sample spoonfuls (or weight in g) of seed required,

VS = number of viable seeds/g and

%VSS = percentage of the viable seed sown that has germinated and survived in the field.

Cost analysis of direct seeding

The costs of tree planting can be very high. Where large numbers are involved, it is wise to consider the direct seeding alternative. A major advantage of direct seeding is the lower costs of the tree establishment, especially where high initial tree densities are needed.

To establish 1 km of a 3 row shelterbelt, the cost of fencing (assuming a new fence is needed on only one side) is currently (1993 prices) about $3,200/km for a fence with 150 treated pine posts at 7 m intervals, rabbit netting with 105 cm mesh, 3 plain 2.5 mm wires, 7 strainers, 8 struts and a gate. The labour charge to erect such a fence may be as much again, but for this example it is assumed that the farmer has done the work without costing the labour. The use of electric fencing may reduce the fencing costs to about $1,000/km (excluding the cost of the energiser), assuming that 5 wires are used and that half as many posts are required. If trees need guarding against hares or rabbits, there are added costs (at least 40 cents per tree), although it may be possible to use additional electrified wires near the ground to do this.

Table 2 gives the approximate costs for conventional seedlings (trees at 75 cents each) compared with successful direct seeding ($200/kg seed) if trees are required at 1 m or 3 m spacing. The other major cost (common to both approaches) is herbicide. The figures assume an application of glyphosate in September (4 L/ha) and October (2 L/ha), a spray of simazine in October (6 L/ha) and in the following autumn, together with an appropriate wetting agent and other chemicals (total cost $250 per 0.45 hectare of sprayed strips). Costs of planting or seeding have not been included.

Table 2 illustrates the large part that fencing contributes to the cost of tree establishment: for planting of seedlings at usual spacing it is about 76% of the total costs (excluding labour) or 50% if electric fencing is used. Tree guards were not included in this analysis, since in many cases they are not essential provided other measures are taken to control such pests as hares, rabbits and wingless grasshoppers.

The cost saving for direct seeding at the higher tree density is estimated to be about $2,000/km of shelterbelt. Such initial high densities are desirable in two situations:

- **defined ground water recharge areas** (the success of tree planting to control deep infiltration of rainwater depends on the leaf area cover). In Victoria, a combination of perennial pasture and high density tree planting (trees on perhaps 10% of the area) may be enough to control ground water accession and hence water table level on the whole farm.
- **agroforestry timberbelts or shelterbelts.** A sufficient density of trees is required to force good early tree form and to allow for a high culling ratio after years 2–10. Without the capacity for a 1 in 3 or 1 in 4 selection it is difficult to produce trees of the desired form, particularly from seedling stock.

Table 2 Relative costs of tree establishment from seedlings or by direct seeding, given two initial tree densities and comparing two types of fencing

Method of tree establishment	Seedlings				Direct seeding			
Type of fencing	Netting		Electric		Netting		Electric	
Tree spacing (m)	3	1	3	1	3	1	3	1
Tree or seed costs ($)	750	2,250	750	2,250	70	200	70	200
Fence costs ($)	3,200	3,200	1,000	1,000	3,200	3,200	1,000	1,000
Herbicides ($)	250	250	250	250	250	250	250	250
Total cost (($)	4,200	5,700	2,000	3,500	3,520	3,650	1,320	1,450
Fence costs as % of total	76	56	50	29	91	88	76	69
Tree costs as % of total	18	39	38	64	2	5	5	14

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