Fire Management in Eucalypt Forest

A. HODGSON

THE ROLE of fire in the ecology of the Eucalypt forests of Australia prior to settlement by Europeans is not well understood. But there is plenty of evidence that fire has been part of the environment for thousands of years. Stocker (1966), Gilbert (1959), and other workers have inferred this from ecological studies. Direct evidence comes from charcoal in river deposits, charred wood in the ground, and historical records (King, 1963) which describe the fires seen by early explorers. But perhaps one of the most remarkable pieces of evidence that fire has been a significant factor in Eucalypt ecology is the development of certain physiological features within the genus which enables it to live with fire. Jacobs (1955) describes these as (1) dormant buds on the trunk and lower branches which will produce epicormic shoots and leaves when the crown is destroyed, (2) lignotubers which can produce new shoots when the stem is killed, and (3) a thick, heat resistant bark which protects the cambium. These features are well-developed in Eucalypts that grow in climates where fire is common. They are less developed in species that grow in wetter climates where fire is rare. *Eucalyptus regnans* is an example of the latter. But even though this species is easily killed by fire it probably owes its existence to fire. It fails to regenerate unless a good seedbed is prepared and the best natural regeneration has always been associated with fire (Cunningham, 1960). Even-aged stands of *Eucalyptus regnans* that are now 275, 110, 48, 40, and

FIG. 1. Twelve months old epicormic shoots resulting from a high-intensity fire. These trees will survive but their commercial value is lowered.

28 years old have resulted from severe fires. Natural regeneration of this species invariably fails unless fire is involved.

Widespread and frequent fires are likely when a hot, dry climate interacts with a heavy flammable forest fuel. Lightning and the hunting fires of the aborigines made this certain in Eucalypt forests before white man came. It seems likely that the aborigines, wildlife, vegetation, and fire had reached some sort of balance. This may not have been a static balance, nor may it have been beneficial to the aborigines but at least they, together with the wildlife and trees, were able to live in an environment where fire was frequent.

After 1800, white man's settlement spread and much forest land was cleared for grazing and agriculture. The role of fire in Eucalypt ecology changed. The aborigines disappeared from many areas and are now no longer an influence except in the north of the continent. Fires which were lit to clear land were severe and were not always confined to the intended area. Forests received more and more protection from fire as forest management intensified. King (1963) concluded that forest fire in recent times is less common than in the past but that the fires that do occur are more intense and damaging than previously.

FIRE EFFECTS ON EUCALYPTS

Eucalyptus species that grow in a severe fire climate can survive a high-intensity fire. Even if the crowns are consumed by the fire the trees rarely die. The response to the fire will depend somewhat on the age of the tree. When a young tree is severely burned, the branches and stems die but the tree will survive by producing several new stems from lignotuberous buds near ground level. Older trees survive by producing epicormic shoots from bud strands on the stem and larger branches.

Both these physiological responses allow the trees to survive a severe fire but from a commercial forestry point of view such trees are severely damaged. Lignotuberous stems rarely produce commercial lumber unless expensive thinning treatments are given and epicormic shoots produce degrade in lumber. Volume growth of these trees is retarded (Hodgson, 1965) and may remain retarded for as long as eight years after the fire.

The amount of damage appears to be related to the fire intensity. Slow-moving fires that burn in light fuel produce little scorching and no measurable damage. There is some evidence (Peet, 1963) that there is an increase in volume production due to low-intensity fires. Fires that are intense enough to scorch more than two-thirds of the foliage on a tree will produce measurable damage. Severe fires also damage other forest values such as wildlife, grazing, and watershed properties.

The damage done by intense wildfires to the commercial forests of southeast and southwest Australia is not compatible with good forest management and it is the task of the various state government fire protection organizations to minimize the damage. This is not easy to do.

EUCALYPT FIRE PROBLEM

The southern part of the Australian continent has a Mediterranean-type climate with hot, dry summers and mild, wet winters. Summer rainfall is not only low but it is unreliable and droughts of two to six weeks are common. Summer high-pressure weather systems feed hot, dry continental air over the forest areas with winds up to 40 mph. Temperatures exceed 100° F several days between mid-December and mid-March. Melbourne at Lat. 37° 49′ South has recorded 114° F, 7% relative humidity, and 40 mph wind. The effect of this sort of weather on fire behavior needs no explanation in this paper.

However, Eucalypt fuel needs particular mention here because it is probably unique among forest fuels in its contribution to fire behavior. Much has been said about the oil content of Eucalypt leaves and its effect on burning. But the oil content is only about 4% of the ovendry weight (Baker and Smith, 1902) and most of this disappears soon after the leaf dies. Pompe and Vines (1966) suggest that the oil content might assist the burning of green leaves but even if this is so, Eucalypt tree crowns will not burn unless heated by a hot ground fire burning below them. Far more important than the chemical composition of the fuel is its abundance and arrangement in the forest. Eucalypts are prolific shedders of dead material. McColl (1966) has measured annual litter accessions of more than 2½ tons per acre. Hodgson (1965) has shown that the accumulation of dead material less than ¼-inch in diameter is about 1¼ tons per acre per annum and that after 12 years of accumulation the additions are still greater than losses by decomposition. This accumulated fuel is nearly all litter; the duff layer that is characteristic of some North American forests is poorly developed.

Some species, such as *Eucalyptus viminalis*, shed a layer of bark annually. This bark strips off in long sheets which curl into hollow tubes as they dry. The tubes or "candles" are often three to eight feet long. When lighted at one end they can be kept burning for as long as 40 minutes. They are natural torches and are often used to light prescribed fires in lieu of a drip torch. Other species have a rough "stringy" bark which splits into chunky pieces of fibrous mate-

FIG. 2. Eucalyptus bark can comprise 30% and more of the total litter weight. This sample weighs 15 tons per acre excluding the woody components more than ¼-inch in diameter.

rial ideal for burning. Fire will climb these stringy barks very readily; in fact, it is the first fuel available for burning after rain. The bark on a standing tree can smoulder for an hour or more, all the time dripping fire onto the ground below. Bark can comprise 30% of the total litter weight. As well, it also has some remarkable aerodynamic properties because it lifts readily in a convection column and is carried long distances by the wind. It is the cause of spectacular "spotting" ahead of a Eucalypt forest fire. Even without a wind, spotting will occur by fire dripping from the bark on branches overhanging a control line. With a light wind, intense spotting up to a quarter of a mile ahead of the fire front is common. As the wind increases, spotting distance increases and there are many cases where it has occurred up to 5 miles and even 10 miles ahead of the fire. In 1964, a convection column over a large fire fractured at 7,000 feet and spread many spot fires as far as 18 miles downwind. This scale of spotting and its importance in fire control puts an aspect on fire control in Eucalypt

FIG. 3. Heavy accumulations of "candlebark" and "stringybark" in a eucalypt forest unburned for 15 years. Both bark types are highly flammable and accelerate fire behaviors by causing "spotting." The "fine fuel" on the ground weighs about 15 tons per acre.

forests that is unknown on this continent. Simple line defense cannot hope to succeed when this happens.

In common with many other fire control people, Australian forest fire controllers have learned that there is no sense in believing they can stop an intense wildfire while it is in full flight. There is just too much energy released too quickly to be affected by any reasonable amount of machinery and manpower that can be pitted against it. If the problem includes a multiple fire front caused by spotting, then

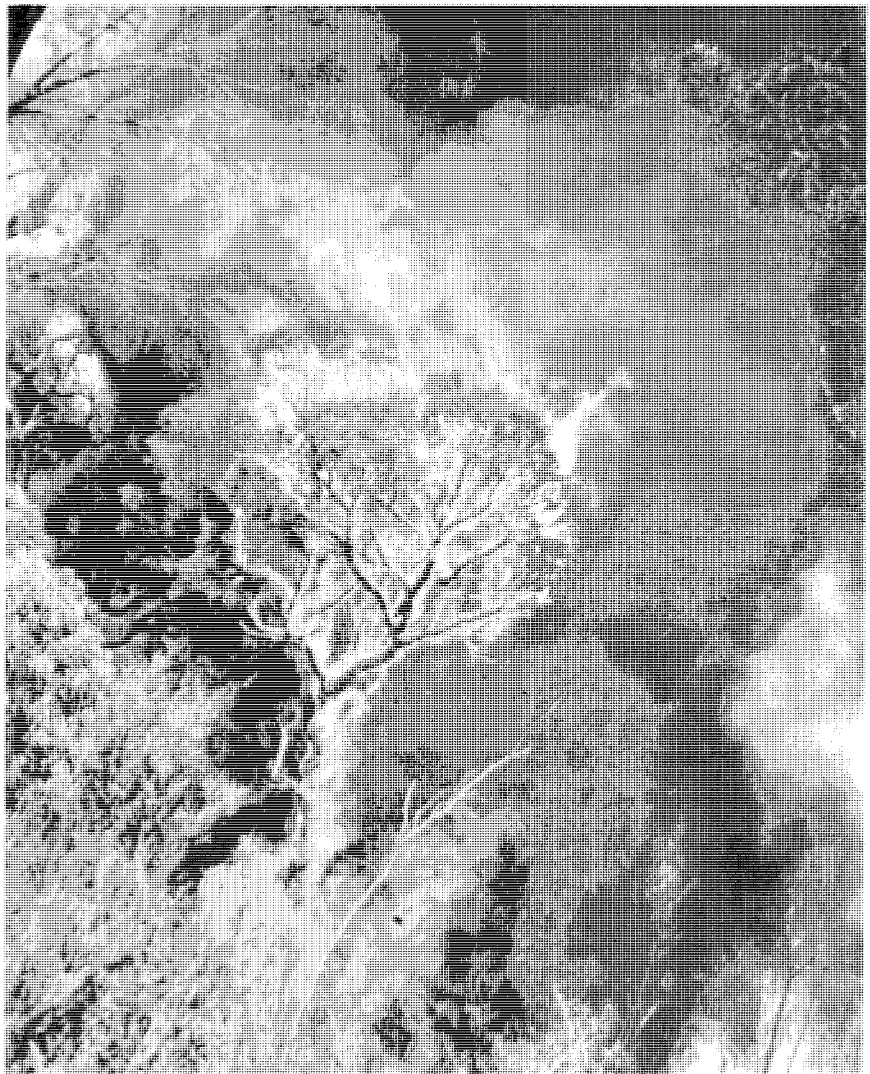

FIG. 4. Elevated fuel allows fire to lift into the tree crowns. Convection column carries burning bark which causes spot fires downwind.

the task is even more hopeless. If the weather changes or the fire runs out of fuel then it is a different matter, but while the fire is in full flight, the sensible thing to do is to organize to take advantage of a more favorable time.

If the whole fire control problem is put into proper perspective, it must be appreciated that only a few fires reach devastating proportions. At least 95% of all forest fires are stopped by the initial attack effort. But the other 5% do most of the damage and despite improve-

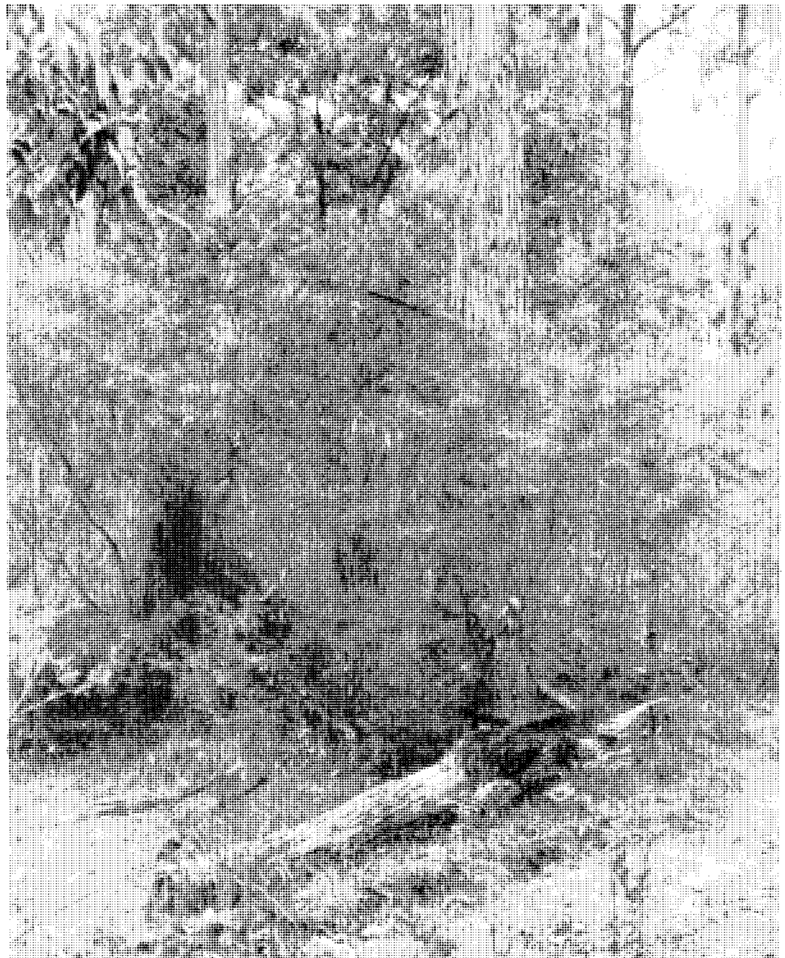

FIG. 5. Understory species in many eucalypt forests add to the total fuel weight and cause dead fuels to be draped above the ground. It is difficult to burn this fuel without high flames.

ments to detection systems and access and despite the latest developments in equipment technology and firefighting techniques, these fires have not been eliminated. They might even be increasing. It seems that they are inevitable if severe weather dries out heavy fuel accumulations.

THEORETICAL APPROACH TO THE PROBLEM

If we look at this problem in its simplest terms, it consists of three things. Namely, (1) the weather which dries the fuel, (2) the fuel itself, and (3) something to start the fire. There is not much that can be done about the weather. There is merit in pursuing certain weather modification projects but even if the best hopes are realized, they will only help a little. They will not solve the problem. And despite the best intended legislation and publicity against fire, the incidence of fires is increasing on government forests.

But the fuel can be altered and it is here that there is real hope of success. If we look at the theoretical possiblities of modifying the fuel we see that fire intensity (I) measured on some appropriate units is the product of the heat of combustion of the fuel (H), the amount of fuel burned (w), and the rate of spread of the fire (r). Byram (1959) expresses this as

$$I = Hwr.$$

Fire intensity is the heat release per unit length of the fire front per unit of time and together with the rate of spread is an excellent description of a fire because it is so obviously related to how difficult the fire is to control and to how much damage the fire causes. In Eucalypt forests it has been found that the rate of spread of a fire is proportional to the amount of fuel burned (McArthur 1962); i.e., r is proportional to w. This relation does not hold for precise studies of fire physics but it holds for fire burning natural fuels over the range of fuel weights normally encountered in Eucalypt forests. This means that if a fire that is burning in Eucalypt fuel weighing, say 4 tons per acre, moves into fuel weighing 8 tons per acre, its rate of spread doubles and its intensity increases 4 times. The spotting distance will increase about 3 times. There is another way in which the significance of fuel weight can be expressed in meaningful terms. A study in 1965, during a 90-day fire season in the State of Victoria in one particular forest area where average fuel weight is about 10 tons per acre, revealed 27 days on which a fire would have had a forward spread of at least 25 chains per hour with flames 30 feet high and throwing spot fires 40 chains ahead. This is uncontrollable and damaging fire behavior. If, however, the fuels had averaged 3 tons per acre, that same fire season would have produced only 1 day when a fire could have exceeded that intensity. A well-equipped and aggressive fire suppression organization would be very successful if it only had to deal with fires in light fuels.

CONTROL BURNING

If heavy fuel accumulations are to be reduced and maintained at a low level over large areas then fire is the obvious tool to use. Chemicals, plows, or scrapers cannot be used over thousands of acres. The planned application of fire over a designated area to reduce fuel and at the same time do little or no damage to the managed timber crop is known as "control burning" in Australia. McArthur (1962) is almost a complete handbook on the basic principles of the subject. Guidelines are being produced which allow these principles to be applied in a number of different forest types and to be compatible with different phases of forest management. In Western Australia the techniques have advanced to the degree that lighting can be done from aircraft (Baxter *et al.* 1966). This is a sensible technique where the fuel is uniform and the topography is flat. In southeastern Australia, steep topography and at least seven different fuel types necessitate more conventional methods.

It is not the intention of this paper to describe how the fuel is reduced by fire but rather to give some justification for why it is done and the extent to which it is done. In terms of the full effect of control burning in Eucalypt ecology we are sadly ignorant. There is no doubt that control burning alters the forest environment. But just exactly what it alters is the key question. Is it altering a natural environment in which forest ecology is in some sort of balance or is it altering something that is not natural?

It seems likely that the heavy fuel accumulations that are found in many forests are not "natural" but are the result of various forest practices and the exclusion of fire from the forests. If it could be guaranteed that all fire could be kept out of these fuels, then this might not be a bad thing, but one of the facts of life is that this cannot be guaranteed. As the fuel gets heavier, the chances of uncontrollable and damaging wildfires get greater. If fine fuel accumulates to 15 tons per acre, then a fire is uncontrollable in moderate fire danger rating weather. There are just too many moderate, high, very high, and extreme fire danger rating days each year to expect that fire can be excluded from these forests for generations.

If control burning alters this "unnatural" fuel then perhaps it is

FIG. 6. This fire has been prescribed with a low-intensity—about 40 BTU/sec/ft—and is reducing fuel without damage to the forest.

not too unreasonable to expect that the change is back toward what was the original condition of the forest floor. The assumption that this is good for all biological aspects of a forest is hard to sustain but it is perhaps not too unrealistic a view. The alternatives must be considered too. Here the evidence is easier to find. If the fuel is not reduced then wildfires are inevitable and do considerable damage. Timber is degraded and growth rate slowed (Hodgson, 1965). Soil is exposed, wildlife is killed, buildings and lives are lost. This is good evidence to use to support the principle of control burning.

The concept of maintaining fuels at a low level by burning is not new in Eucalypt forests; it has been practiced for many years. But its application on a systematic and repeated basis to achieve specific objects and backed by guidelines based on research is better developed now than ever before. It is not a scorched earth policy to eliminate hazards and prevent forest fires. It reduces the amount of fuel available for burning by a wildfire so that the wildfire can be easily controlled and/or does very little damage. Control burning does not reduce the need for aggressive and efficient fire suppression efforts, it merely gives them a better chance of being successful.

Because its aim is to prevent damage by severe wildfires it must be

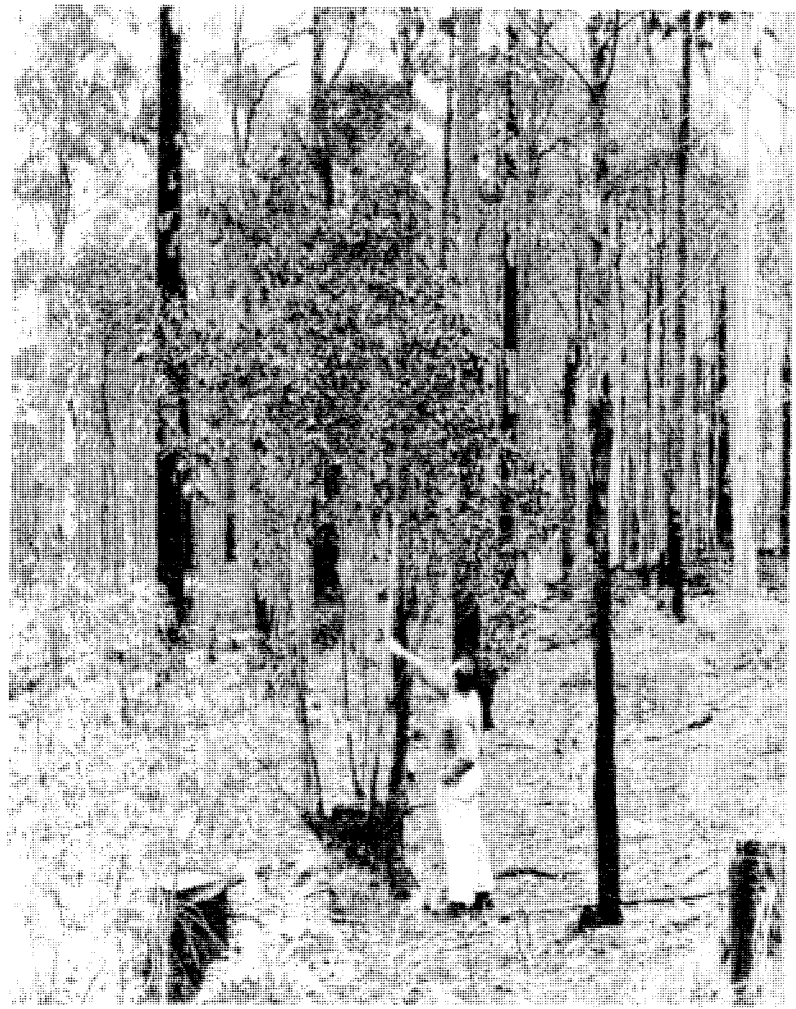

FIG. 7. Eucalypt forest as it appears one month after a successful control burn. The remaining fuel is light and the flammable bark on the trees has been burned. The coppice stems in the foreground are of no value in this forest but they indicate that scorching was no more than about 15 feet above ground.

applied in depth to catch spot fires from wildfires. Control burning in strips less than half a mile wide is not favored except along some roadsides where fires frequently start. The general practice is to apply fire to large units of forest each several thousand acres in area. This cannot be done in one burning period but the burned area is built up block-by-block when conditions are suitable throughout a burning season. Since wildfire damage potential is greatest in high-value forests, it is sensible to control burn within these forests rather than around them. This is not always possible because burning must be compatible with silviculture, but it is a sound principle that is followed whenever possible.

Current Control Burning Program

Australian forests are largely state-owned and operated and control burning policies differ from state-to-state. With the possible exception of Western Australia, State forest services do not have the manpower or finance to do control burning over all the forests. Just what is a desirable goal in terms of the area burned annually is not clear but in the State of Victoria a tentative goal has been set at 750,000 acres annually. This figure is a short-term compromise between what is desirable and what is believed can be achieved if existing resources and skill are applied to the task intelligently. Victoria has 9 million acres of forest on which fire can be used successfully. If fuel is to be kept within the limits of one to six tons per acre, any one area will need burning every four or five years. An annual burning program of three-fourths million acres will, in a 4-year burning cycle, keep fuel within those limits on about 3 million acres or one-third of the total area suitable for burning.

If this 3 million acres is selected wisely to include areas with a high incidence of fires and areas carrying high-value forests, this program could conceivably result in a reduction of damage by wildfires by at least half of that done if control burning is not practiced. This policy is not a complete answer to the forest fire problem and it will have to be reviewed when more is known about the results achieved. Progress toward achieving the control burning area goal is illustrated in the following table.

Season	*Area fuel reduced by control burning*
1960-61	21,451 acres
1961-62	68,584
1962-63	145,629
1963-64	95,375
1964-65	190,633
1965-66	464,579

RESULTS

Results in terms of damage prevented are impossible to measure. But recently in Victoria there have been several notable instances where the effect of control burning on wildfires has been obvious and spectacular. On one occasion a wildfire started in grassland and quickly spread to forest. The fire danger was high and the fire immediately crowned in the trees and was impossible to control. It then ran into an area that had been control burned six months previously. It immediately fell out of the treetops and became a slow-moving ground fire. A crew, equipped with hand tools, easily controlled the perimeter and the many small spot fires that were struggling to survive in the light fuel. If the defense had not been present, the weather and fuels were such that the fire would have run another eight miles through high-value forest before there would have been any chance to control it. On other occasions, fires have started in the light fuel on control burned areas and have failed to develop even though the fire danger was high.

COSTS

Actual costs of control burning in recent years in Victoria have varied from \$0.07 to \$0.40 per acre, including the cost of constructing control lines. The two greatest influences on cost are the ease of control and the perimeter length/area ratio of the area burned. Small areas cost more per unit area but there is a maximum area beyond which a crew cannot complete the job in one burning period. In the right weather conditions, a five-man crew can burn 600 to 800 acres in one operation and the cost will be about \$0.10 per acre.

This is cheap and effective insurance against damage by wildfires.

ACKNOWLEDGMENT

Six of the photographs presented with this paper were provided by the Forests Commission of Victoria, and are gratefully acknowledged.

LITERATURE CITED

Baxter, J. R., Packham, D. R., and Peet, G. B. 1966. Control burning from aircraft. CSIRO Chemical Research Laboratories, Melbourne, Australia.

Byram, G. M. 1959. Combustion of forest fuels. Chapter 3 in Forest Fire: Control and Use by K. P. Davis.

Cunningham, T. M. 1960. The natural regeneration of Eucalptus regnans. Bull. No. 1, School of Forestry, Univ. of Melbourne.

Gilbert, J. M. 1959. Forest succession in the Florentine Valley, Tasmania. Pap. Proc. Roy. Soc. Tas. 93.

Hodgson, A. 1965. Unpublished data. Forest Commission–Victoria.

Jacobs, M. R. 1955. Growth habits of the Eucalypts. F.& S.T.B. Canberra.

King, A. R. 1963. Report of the influence of colonization on the forests and the prevalence of bushfires in Australia. C.S.I.R.O. Melbourne.

McArthur, A. G. 1962. Control burning in Eucalypt Forests. F.& S.T.B. Leaflet No. 80, Canberra.

McColl, J. G. 1966. Accession and decomposition of litter in Spotted Gum Forests. Aust. For. Vol. 30, No. 3, pp. 191-198.

Peet, G. 1964. Western Australian Forest Service–personal communication.

Pompe, A., and Vines, R. G. 1966. Influence of moisture on the combustion of leaves. Aust. For. Vol. 30, No. 3, pp. 231-241.

Stocker, G. C. 1966. Effects of fire on vegetation in the Northern Territory. Aust. For. Vol. 30, No. 3, pp. 223-230.