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FUEL MOISTURE CHANGES UNDER RADIATA PINE

RESEARCH REPORT NO. 13
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Originally printed as Fire Research Branch Report No. 13, Forests Commission, Victoria

SUMMARY

Moisture movements in the duff, litter and elevated needle fuels under radiata pine (*Pinus radiata, D Don*) were studied in two stands near Myrtleford. The curing of needles on radiata pine thinning slash in mid-spring and early summer was also studied.

A guide was developed to allow prediction of changes in the litter moisture content using current litter moisture content and relative humidity. Trends in the moisture movements in each fuel type were defined. Duff moisture was found to fall substantially during the day. The needles on the thinning slash required 60 days to cure in mid-spring and 35 days in early summer.

INTRODUCTION

The fine fuel moisture contents suitable for low intensity burning in radiata pine (*Pinus radiata, D Don*) plantations have been defined by Thomson (1978) and Billing (1979), and direct measurement is possible using the Speedy Moisture Tester (Dexter and Williams, 1976). However, the planning and implementation of burning operations can be further assisted by an understanding of the moisture changes that occur within plantation fuels.

This report discusses the results of a study of needle fuel moisture movement in two radiata pine stands of markedly different stocking, and includes a model of moisture movement in needle litter derived from the results. It also discusses a study which examined the rate of needle curing in thinning slash.

STUDY AREAS

Moisture movements were studied in two stands in the Merriang Plantation, 10 km south of Myrtleford. Because canopy density affects the amount of direct sunlight reaching the forest floor, and air movement within the stand, stand density can affect the fuel moisture regime. The stands were therefore selected to represent extremes of stocking (Table 1). The first stand was planted in 1962 on gently sloping ground and was unthinned and unpruned. The second was planted in 1951, located on gently sloping ground and had been selectively pruned to 3 m and thinned at least three times, with the last thinning only two months before the study commenced.

The curing was also located in the Merriang Plantation in a stand which had been planted in 1962. The stand had received a delayed first thinning two months before the study commenced.

TABLE 1: STAND CHARACTERISTICS AT TIME OF STUDY

Study	Age	Stocking (stems/ha)	Site Index (m)	Top Height (m)	Basal Area (m^2/ha)
Moisture Movement	17	1313	28.8	29.9	78.0
	28	204	31.1	36.9	57.9
Curing	18	288	32.1	29.5	23.9

METHOD

Moisture content changes in the duff[1], needle litter[2] and elevated needle fuel[3] layers were recorded for periods varying between five and ten hours on seven days, and for a further 24 hour period on two other days. Sampling was conducted in November and December 1978 with one 24 hour period sampled in March 1979. The moisture content of the needle litter was determined after oven drying samples at 105°C, while moisture changes in the duff and elevated needle layers were assessed by periodically measuring the change in weight of samples placed within the fuel bed. Preliminary work had shown that weighing samples gave results comparable with oven drying, and in the elevated and duff fuels this technique overcame problems caused by the destructive sampling necessary for oven dry weight determinations.

Three trays of fuel to determine duff moisture contents and three mesh bags containing needle fuel, to determine elevated needle fuel moistures, were used in each stand. Measurements were taken every two hours through the day and every four hours at night throughout the two 24 hour sampling periods. Hourly measurements were taken in the shorter sampling periods except for the duff layer where, to minimise disturbance to the fuel bed, two hourly measurements were taken.

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[1] Duff is the layer of decomposing litter between the surface fuels and mineral soil.

[2] Needle litter is the top layer of dead pine needles on the plantation floor. This layer is more compacted than the elevated dead needles but better aerated than the duff layer.

[3] Elevated dead needles refer to dead pine needles lodged on branches, vegetation or debris on the forest floor so that they are well aerated and above the ground.

A thermohygrograph was used to obtain a continuous record of temperature and relative humidity at 1.3 m above ground within each stand, and at each measurement of moisture content a probe designed by CSIRO (McIlroy, 1955) was used to obtain temperature and relative humidity at ground level. The probe was cumbersome and could only be used in one stand each day and, as it could not be used at night, no ground level records were taken when the sampling period was 24 hours.

The study of the curing of needles on slash was conducted during the early summer of 1980 and spring of 1981. Five trees were felled in December 1980 and a further seven in October 1981. Several branches were lopped from each tree and the butt diameters of each branch recorded. Needles were collected from these branches and the heads of the trees at least once a week and their moisture content determined after oven drying at 105°C.

RESULTS AND DISCUSSION

1 Moisture Movements

The thinned stand had significantly ($p = 0.05$) lower minimum and higher maximum daily temperatures than the unthinned stand. In the thinned stand the relative humidity fell to significantly ($p = 0.05$) lower values during the day and at night it took longer to reach 100%, although it started falling at the same time during the morning in both stands.

The ground was bathed in direct sunlight for much of the day in the thinned stand but in the unthinned stand direct sunlight reached the ground only rarely. This meant that the differences in temperature at ground level between the stands were far greater than the differences at 1.3 m. The temperature and humidity probe revealed that in the thinned stand the temperature at ground level was an average of 5°C warmer during the day than the temperature at 1.3 m, whereas in the unthinned stand the ground temperature was, on average, 2°C cooler than the screen temperature. These differences in microclimate were reflected in the fuel moisture within each stand. Fuels in the thinned stand were normally drier, and this was particularly so for the duff layer where the average moisture content at 1200 hours was 123% of oven dried weight (ODW) less than in the unthinned stand.

The moisture content of the litter and elevated needle fuels rose in the cool, moist conditions at night and then decreased rapidly as the temperature increased in the morning. Although fuels were normally drier in the thinned stand during the day, the moisture contents of the needle litter in both stands rose to similar values at night, as did the moisture contents of the elevated needle fuels. The moisture contents of the needle litter rose to higher levels at night than that of elevated needle fuels and by early morning there was a large difference in moisture content between the elevated needle fuels and the litter. This difference rapidly dimished as the day progressed and for most of the daylight period the moisture content of the elevated needle fuels was within 5% ODW of the needle litter moisture content. By mid-afternoon the moisture contents of these fuels had reached their lowest values and they began to rise again in the cool of the evening.

For the November and December observations in the unthinned stand the mean hourly moisture loss from the duff layer was relatively constant at 3.5% ± 0.6% (95% confidence limits) with a range from 1% to 8%. A constant rate of moisture loss is characteristic of very wet fuels (Van Wagner, 1970) and the duff in the unthinned stand was in this category since its moisture content generally exceeded 150%.

In the thinned stand, if the initial duff moisture content was greater than 50% ODW the moisture loss was rapid with a decrease exceeding 40% ODW in seven hours on three occasions. If the initial moisture content was less than 50% ODW the loss rate was slower and the duff began to absorb moisture in the late afternoon. In fact, during the 24 hour sampling period in March, when the duff moisture content ranged from 15-25% ODW the fuel moisture responded to changing temperature and relative humidity conditions in much the same way as the other fuel types. The onset of cool, moist conditions at night did not increase the duff moisture content appreciably when the duff was wet.

Thomson (1978) recommends a duff moisture content greater than 40% ODW for fuel reduction burning and in view of the size of the moisture losses recorded, it should be checked occasionally if it falls below 80% ODW.

Figure 1 shows the fuel moistures recorded in each stand throughout the 24 hour sampling period in November. It is a useful summary of the daily changes in fuel moisture that are possible and it illustrates:-

(a) variations in moisture content are likely to be more pronounced in thinned stands i.e. those exposed to greater fluctuations in temperature, relative humidity and air movement.

(b) the fuel moisture differential which commonly exists between elevated fuels and litter fuels.

(c) significant moisture loss from the duff layer can occur in a few hours if the initial moisture content is high.

(d) the moisture content of the needle fuels can change rapidly from levels where burning is difficult to sustain to levels where moderate to severe fire intensities can occur.

2 Litter Moisture Model

The data obtained were used to develop a model which allows prediction of needle litter moisture conditions suitable for fuel reduction burning. The model will assist when planning a fuel reduction burn as it provides an indication of the time at which the needle litter moisture content becomes low enough to commence burning. It also gives some warning if the needle litter moisture is likely to become too low for safe burning.

The rate of change of fuel moisture content is affected by the difference between the current fuel moisture and its equilibrium moisture content (EMC) (Schroeder and Buck, 1970). The EMC is the moisture content which is finally attained uniformly through materials exposed in an atmosphere of fixed temperature and humidity, and without external heating and cooling. Blackmarr (1971) developed EMC curves for several species by varying the humidity

FIG 1 : FUEL MOISTURE CHANGES OVER 24 HOURS

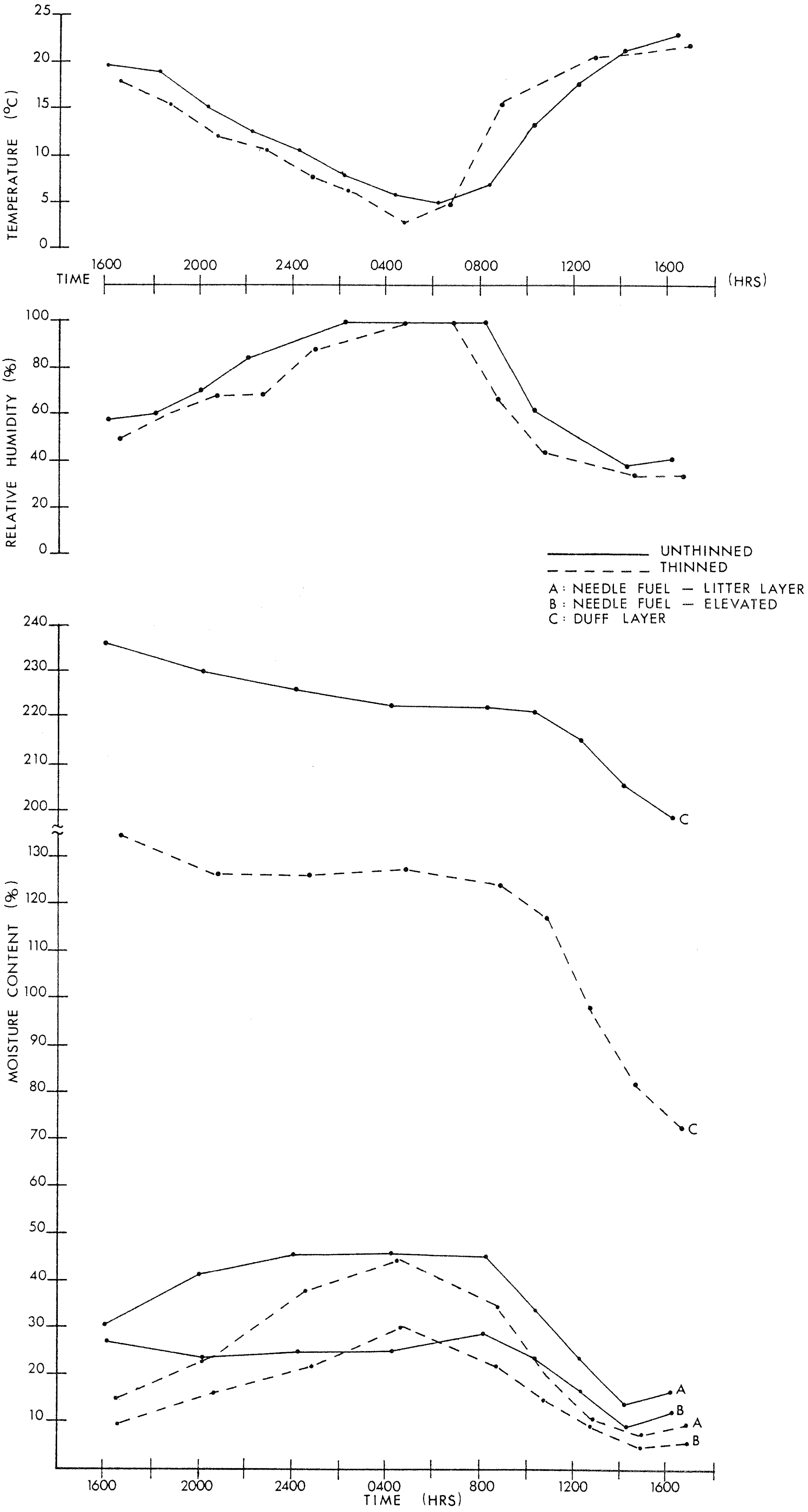


FIG 2(a) : EQUILIBRIUM MOISTURE CONTENT – P. taeda

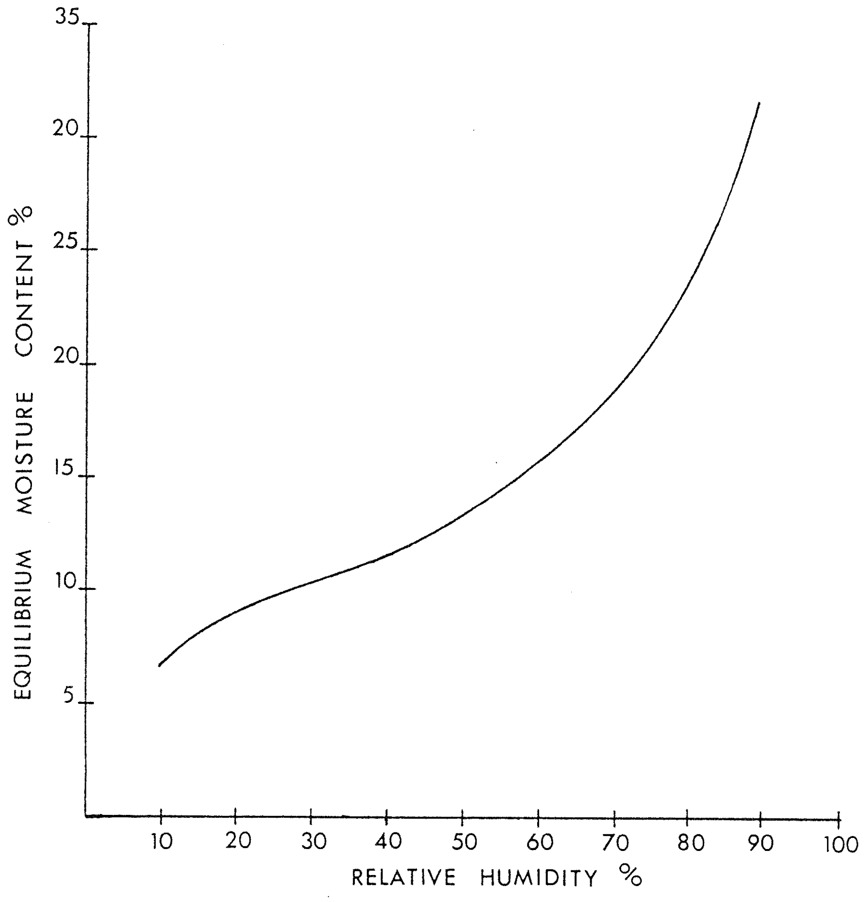
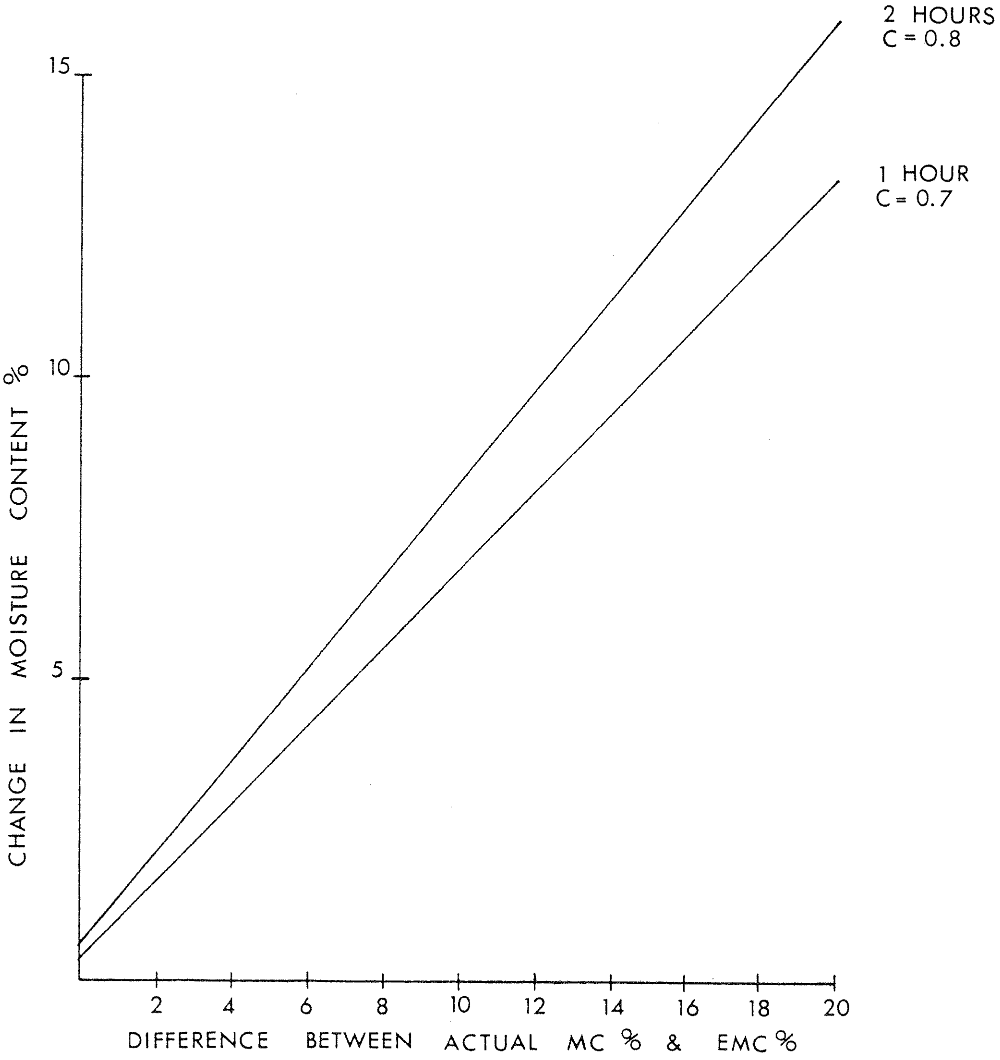


FIG 2(b) : CHANGE IN LITTER MOISTURE CONTENT



while keeping the temperature constant at 27°C, and although radiata pine was not among the species tested, a curve was developed for loblolly pine (*Pinus taeda*), a similar species (Fig. 2(a)). Using this curve the differences between the actual needle litter moisture contents and the equilibrium values were calculated[1]. These differences were then used in regressions against the changes in needle litter moisture that occurred over both the following one and two hours. Changes in needle litter moisture that occurred after two hours were not considered because using the current relative humidity to predict the moisture content two hours in advance assumes that the rate at which the relative humidity and hence the EMC will change in that time will be constant. This assumption becomes less reliable when applied for long periods and two hours was thought to be the limit for reliable estimates. The regressions were significant ($p = 0.01$) (see Fig. 2(b)) but apply only to needle litter that is losing moisture.

To predict the changes in fuel moisture content under drying conditions, the following procedure is used:-

(a) measure the existing fuel moisture content and relative humidity, eg MC = 22%, RH = 50%.
(b) determine the appropriate EMC from Fig. 2(a) - (13.5%).
(c) use the difference between the actual moisture content and the EMC (8.5%) and the graphs in Fig. 2(b) to determine the likely moisture loss in the next one hour (5.5%) and the next two hours (7%).
(d) the actual moisture content in one hour (16.5%) and two hours time (15%) can then be calculated.

The EMC is influenced by temperature as well as relative humidity. When developing the EMC curves Blackmarr (1971) used a temperature of 27°C, which is above the temperature recommended for fuel reduction burning (Billing, 1979). However, the variation in EMC

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[1] Results from similar work by D Williams were also included

due to temperature is only slight (Blackmarr, 1971) and the use of this curve should not introduce any substantial errors of prediction.

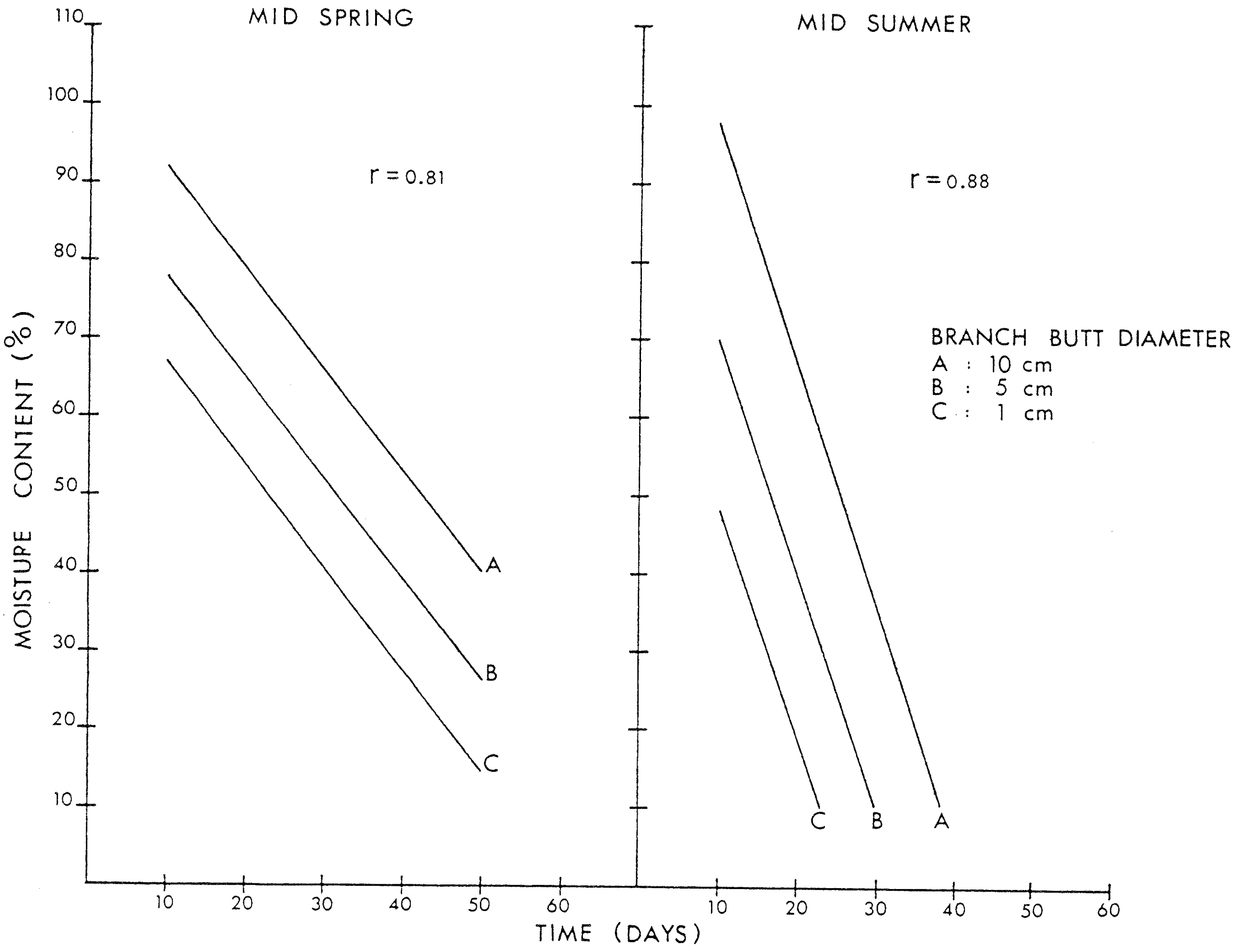
The model provides an indication of likely changes in fuel moisture content but during burning operations periodic remeasurement of fuel moisture is still essential to check the forecast trends.

3 Curing of Slash

An examination of weather records for the area showed that early summer 1980 was much warmer than average and that the temperatures that occurred in mid-spring 1981 were about average. Because fuel reduction burning in pines should be done in spring the results will be valid for most fuel reduction burning operations. The results should also apply to trees felled through the winter because the fuels from these trees will probably not begin to cure until early spring

The moisture content of the needles on the slash was found to be significantly ($p = 0.01$) related to both the time since the trees were felled and the butt diameter of the branch or head to which the needles were attached. These regressions are shown in Fig. 3. Williams (1977) found that when the moisture content of the elevated needles is from 25-35% ODW they will just ignite and can only carry a fire with the assistance of wind. Fig. 3 shows that in mid-spring the needles on the larger heads required about 60 days to cure to this moisture content range while in early summer only 35 days were required for the needles to reach this level of flammability.

FIG 3 : MOISTURE CONTENT OF ELEVATED NEEDLES ON THINNING SLASH



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