WOOD PRESERVATIVE TESTING USING SOIL BED TECHNOLOGY.

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Abstract

Soil beds or accelerated field simulators are finding increasing use in the development and testing of new wood preservatives. Our knowledge about the parameters affecting decay under such conditions is still rudimentary and, to a certain extent the applicability of soil bed results to field exposure and expected service life is poorly understood. This paper reports on recent developments with soil bed technology and points to the future direction for this test procedure.

The performance of chromated copper arsenate type C (CCA-C) treated southern yellow pine in an accelerated soil bed facility was compared with that of matched material in more conventional ground contact stake tests. Rates of decay in each exposure condition were examined using statistical curve fitting analysis. The "acceleration" of decay in the soil bed environment is discussed, along with the environmental parameters which influence it.

Introduction

Ground contact stake tests are an important tool in the development and testing of new wood preservative formulations. This is particularly true in North America, but also in other regions. Over a period of many years considerable knowledge and experience has been built up about the relativity of field stake test results and expected in-service life. More recently, in response to market demands for new products, soil bed or accelerated field simulators have seen increasing use for this same purpose. In theory such procedures accelerate decay processes yielding performance results much faster than would be obtained in conventional field stake tests. Soil beds, accelerated field simulators or fungus cellars or terrestrial microcosms have been in use for some considerable time (Gersonde and Becker 1958; Hedley, 1980; Johnson *et al.*, 1982; Nilsson and Edlund, 1995; Preston *et al.*, 1983; Vinden *et al.*, 1982). However, the technology has not advanced to the point where the results are considered equivalent to, and as useful as, field test results. Soil bed data are still regarded with some skepticism by industry and academia alike because there has not been sufficient time to develop a good track record with the test procedure. In 1993 a soil bed test method was standardised by the American Wood Preservers' Association. This standard, designated E14-93 (AWPA ,1996), has helped to put soil bed technology on a more scientific footing but further development of the concept is necessary to gain universal acceptance. A series of papers since that time have reported on slow but steady progress (Archer and Morrell, 1994; Nicholas and Archer, 1994). The current focus of soil bed studies is on the interaction of preservative component depletion, soil moisture relationships, the influence of soil type, soil microflora, improved assessment procedures and data interpretation. This paper reports on some of these activities underway at the CSI laboratories in Harrisburg, NC and at other laboratories throughout the USA

Methods

Southern yellow pine sapwood stakes (5 x 19 x 200 mm or 19 x 19 x 450 mm) were treated with CCA-C preservative using a conventional vacuum pressure process. Samples were treated to achieve a series of nominal retentions ranging from 1.0 to 9.6 kg/m^3 active ingredients (oxide basis). Individual stake retentions were determined from pre- and post-treatment weights. Following treatment the material was stored in plastic at ambient room temperature for 10 days to allow fixation to occur. After fixation the stakes were allowed to air-dry in preparation for exposure in soil.

Three different soil exposure regimes: a soil bed, a forest site (mixed hardwood and softwood) and an open grassy field all located in Harrisburg, NC were used to challenge the stakes. All three exposure regimes shared the same soil type which, using standard soil classification criteria (Glinski and Lipiec, 1990), could be described as a sandy loam. Full details of the soil chemistry and physical characteristics have been reported by Archer and Morrell (1993). Average soil temperature in the forest for the duration of the study was 15°C (range -1°C to 28°C), whereas in the open field, the average value was slightly higher at 18°C (range 0°C to 36°C). Soil moisture levels fluctuated with the change in the seasons and with rainfall.

Soil beds were constructed from plastic lined concrete burial vaults (2 x 1 x 0.75m) as described by Archer and Morrell (1993). Individual burial vaults were maintained in a modified double skinned plastic tunnel greenhouse covered with a horticultural shade cloth giving approximately 80% light transmission. Humidity within the greenhouse was not precisely controlled and ranged from 40 to 70% R.H. Soil temperatures in the beds averaged 26°C for the duration of the experiment (range 22°C to 28°C). The soil was watered from above with an automated spray system controlled by soil vacuum devices (Irrometers). Soil moisture content was maintained at about 50% of the water holding capacity as defined by Marshall (1959) or 15-18% moisture content as measured by the oven dry method. Previous studies (Archer, 1991) have shown that these moisture levels promote basidiomycete decay.

The 5 x 19 x 200 mm stakelets were used in the soil bed and forest and the 19 x 19 x 450 mm material was employed in the exposed field only. Ten stakes from each retention group were exposed in each of the three environments.

Stakes were inspected at increasing time intervals using a visual rating system based on a modified AWPA standard E-7 (AWPA, 1996) scheme. Termite attack was not a factor in the exposure hazard. Decay ratings were converted to percent soundness values as illustrated in Table 1 below.

Finally, to assess the reproducibility of the procedures, data from a second experiment installed 12 months after the first, using the same soil bed and forest exposures locations was examined.

Table 1: Decay rating system

Rating	Percent soundness	Description
10	100	no decay
9	99	trace or suspicion of decay
8	90	minor but established decay
7	75	progressive decay
6	70	well established decay
5	65	advanced decay
4	40	severe in danger of failure
0	0	failed

Results and Discussion

For the soil bed procedure to be of use to the wood preservation researcher, it must provide some tangible benefit or advantage over conventional field test approaches. The major advantage of a soil bed is that rates of decay are generally faster. However, It is important that such accelerated decay is applicable to decay processes in the "real" world. It needs to be demonstrated that different preservative systems perform relative to each other and fail to the same decay types in soil beds as seen in the natural exposure conditions. Until this occurs soil bed testing will not achieve the recognition it deserves.

Performance of the test material under the three exposure conditions can be seen in Figures 1 - 3. The similarity of the decay curves and the relativity of the retention levels make interesting comparisons. Time to failure is one measure of the rate of decay, and using this criterion, it is apparent that the untreated controls take about 58 months to fail in the field, 35 months to fail in the forest, and 24 months to fail in the soil bed. Similar trends are evident with the treated material, but because only the 1kg retention is the only retention level that has failed in both the forest and field tests, few actual comparisons can be made. However, the data show that the 1kg retention decays completely after 90 months in the forest and after 30 months in the soil bed. While this result would indicate a three-fold acceleration factor in the soil bed, it has been established by other workers, that time taken to failure for untreated material is a poor basis for comparing preservative performance (Hartford and Colley, 1981; Link and DeGroot, 1989).

With increasing CCA retention the length of the lag phase before the onset of decay increases. The length of the lag phase has been considered extremely important in regard to the overall efficacy of a preservative system (King *et al.* 1989; Vinden *et al.* 1983). Figures 1-3 show that the lag phase for any given CCA retention is shorter in the soil bed than it is in the other environments. This would suggest that decay rates in the soil bed are higher than in the forest or field sites. To calculate the magnitude of this acceleration factor, straight line regression equations of the form **$y = ax + c$** were fitted to each of the curves (Figure 4). With these simple linear equations, R^2 values in excess of 0.98 were obtained. Comparing the slope or 'a' values for each curve we find that the soil bed yields an 'a' value of -4.22, the forest an 'a' value of -2.86 and the open field an 'a' value of -1.8. These data indicate that untreated southern pine decays about twice as fast in the soil bed as it does in the field and about 1.5 times the rate observed in the forest. While this is a positive result it might be surprising that the magnitude of the increase is so small. However, this value depends very much the rate of decay in the field site where the comparison is made. If the rate of decay in the field is intrinsically high, as in the Harrisburg site, then the relative increase observed in the soil bed will be correspondingly small.

While a simple straight line regression could be fitted to the untreated control curves this is not appropriate for the treated material because of the extended lag phases exhibited by the data. Interestingly, Morris and Cook (1994) attempted to fit straight line regressions to data from treated material in a field test with some degree of success. Their fundamental assumption in doing this is that the rate of decay from 100% sound to failed is constant. This may have been valid for Morris and Cook's data because of the relatively short time span for which the data was available, but for the data presented here, other non-linear equations seemed more appropriate. A number of options were generated using sophisticated curve fitting software, but of these, the equation for a classic asymmetric sigmoid curve seemed the best. The general form of this curve is:

$$y= a+b/(1+\exp(-x-d\ln(2^{1/c}-1)-c)/d))^{e}$$

where 'a' represents the transition magnitude or height, 'b' represents the mid point of the transition, 'c' controls the width of the transition and 'd' controls the shape of the transition (Jandel Scientific, 1996). For the purposes of this discussion here the 'c' parameter is most relevant. It can be further defined as the 'x' value between the $Y_{min} + 0.75^{*} Y_{range} + 0.25 * Y_{range}$. In practice this equates to the exposure time when the average stake rating reaches 50% sound.

Figure 5 compares the performance of the 2kg retention of CCA-C in the soil bed, forest and field sites. Actual data are plotted along with the predicted curve from the asymmetric sigmoid model. It is apparent that the curve fits the data well and this is confirmed by the R^2 values which ranged from 0.98 to 0.99. The value of the 'c' parameter for each of these curves is as follows: Soil bed 28; Forest 55; Field 64; This result suggests that the rate of decay in the soil bed is twice that of the forest and field sites and is in agreement with the data for the untreated material. Further work is necessary to fully understand the usefulness and validity of this approach to looking at the data. What is needed is a model which will accurately predict the time to failure or some other yardstick in as short a period as possible. One of the difficulties with this approach is that the shape of the curve and thus the equation for the model is heavily dependent on the minimum value of Y or when the material fails. This value is unknown for the field site at this point and consequently the equation for the curve is suspect.

Experience from the coatings industry may be of use in this area. In a recent review paper Martin et al. (1994) summarise the application survival analysis to the predict when coatings will fail in service. This approach permits the prediction of time to failure (however it is defined) from the failure of the first sample in a number of replicates using a Weibull probability function which bears some resemblance to the model utilised here.

Performance data for CCA-C treated 5 x 19 x 200 mm stakes in another decay test installed at the same locations are presented in Figures 6 and 7. These data can be compared with the data presented in Figures 1 and 2. While the shape of the decay curves and the relativity of the retention levels between the two data sets is the same, the decay rates are not. This result might be expected for the forest site, since the micro-environment and hence the decay rate are subject to the vagaries of weather. However, the results for the soil bed should be more reproducible from one experiment to the next because the environmental parameters are more carefully controlled. To explain this anomaly the soil moisture levels in the soil beds for the duration of the second experiment were examined. The soil was actually slightly wetter than expected, closer to 60 % of the water holding capacity instead of the intended 50% water holding capacity. The importance of soil moisture levels to decay type in a soil bed has been summarised by Archer (1991). The data presented in Figures 8 A and 8B (courtesy of D. Nicholas Mississippi State University) illustrate that soil moisture levels in the region 40 and 60 % of the field capacity have a marked effect on stake moisture levels. The data suggest that at a soil moisture level close to 50 % of the field capacity stake moisture contents jump up rapidly from 30 to 80%. At these elevated moisture contents soft rot fungi would be favoured over basidiomycetes resulting in lower decay rates.

The depletion of preservative components and the influence of this phenomenon on performance is being actively studied. Archer and Jin (1994) reported on how soil cation exchange capacity influences the depletion of CCA components from southern yellow pine in a soil bed. Some of the data after 12 months exposure is reproduced in Figure 9. It is apparent from this preliminary work that soil chemistry plays a key role in depletion processes. Work underway at Mississippi State University aims to evaluate the influence of different soil types on depletion and the ultimate goal of this effort is to incorporate depletion results into performance evaluation in some form of covariate statistical analysis.

Summary and Conclusions

In summary, soil beds, accelerated field simulators or fungus cellars become more popular in recent years as a direct consequence of a need to develop and screen new formulations for wood preservative applications as rapidly as possible. The research activity described here and in progress at several other institutions is leading to a better understanding of the fundamental processes which influence the decay of treated wood in soil contact. At the same time we are learning how those processes may be optimised to develop a credible procedure for the accelerated testing of new preservative formulations.

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Figure 1: Performance of 5 x 19 x 200mm southern yellow pine stakelets treated with CCA-C in a forest site.

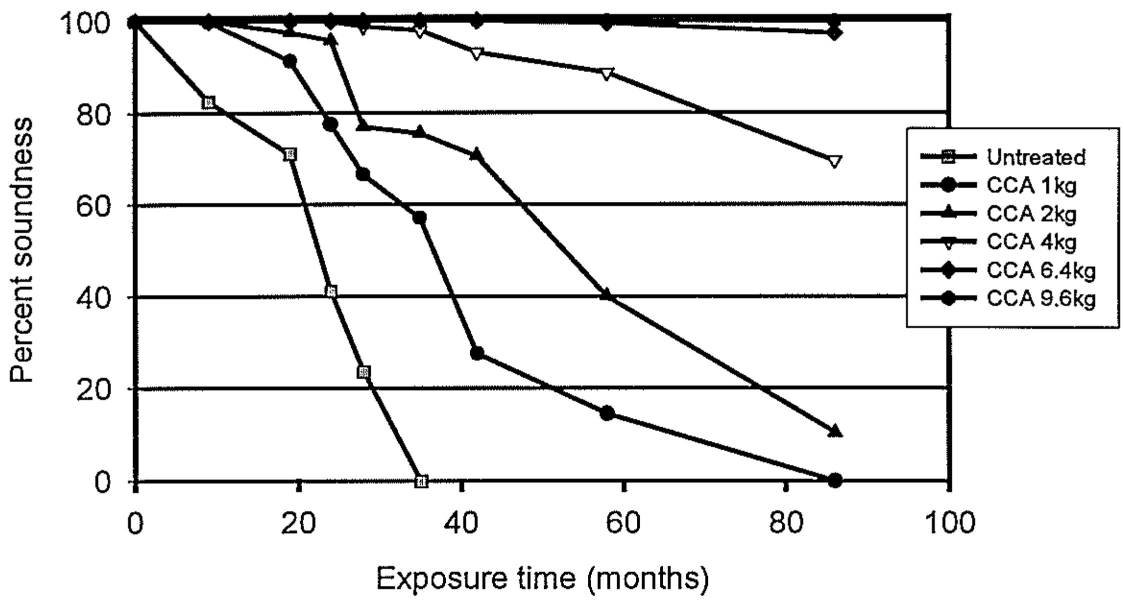


Figure 2: Performance of 5 x 19 x 200mm southern yellow pine stakelets treated with CCA-C in a soil bed

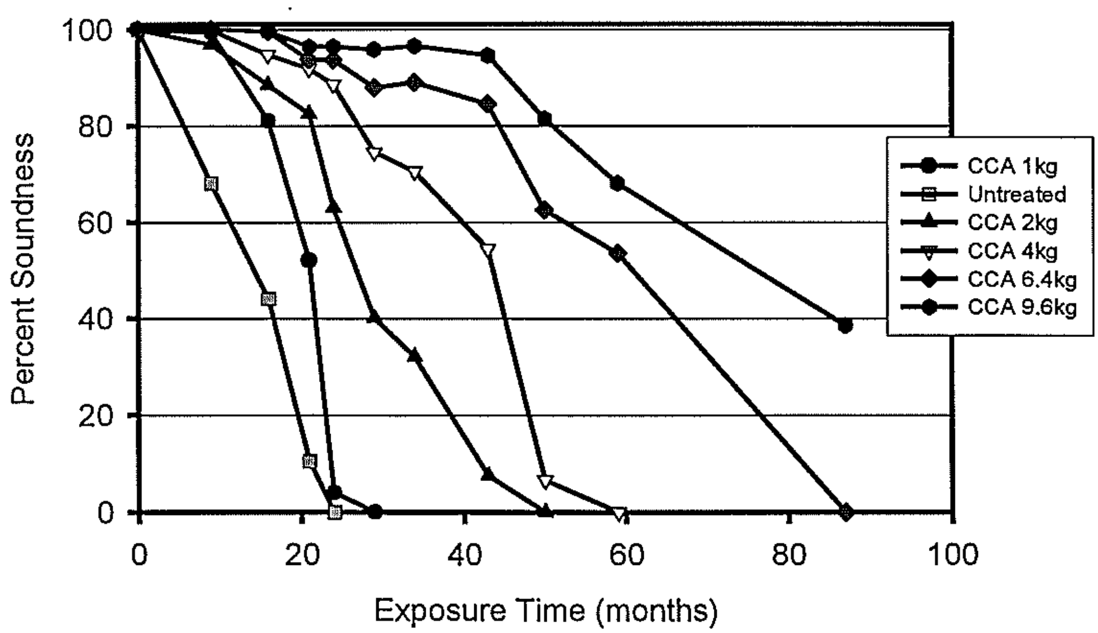


Figure 3: Performance of 19 x 19 x 450mm southern yellow pine stakes treated with CCA-C in a field site

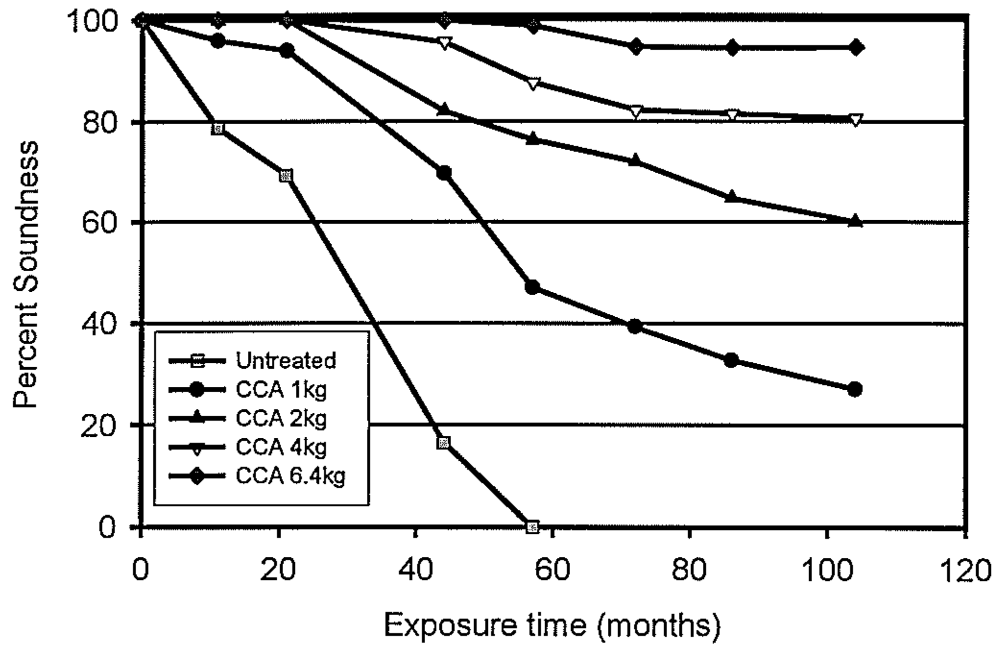


Figure 4: Comparative decay rates for untreated SYP

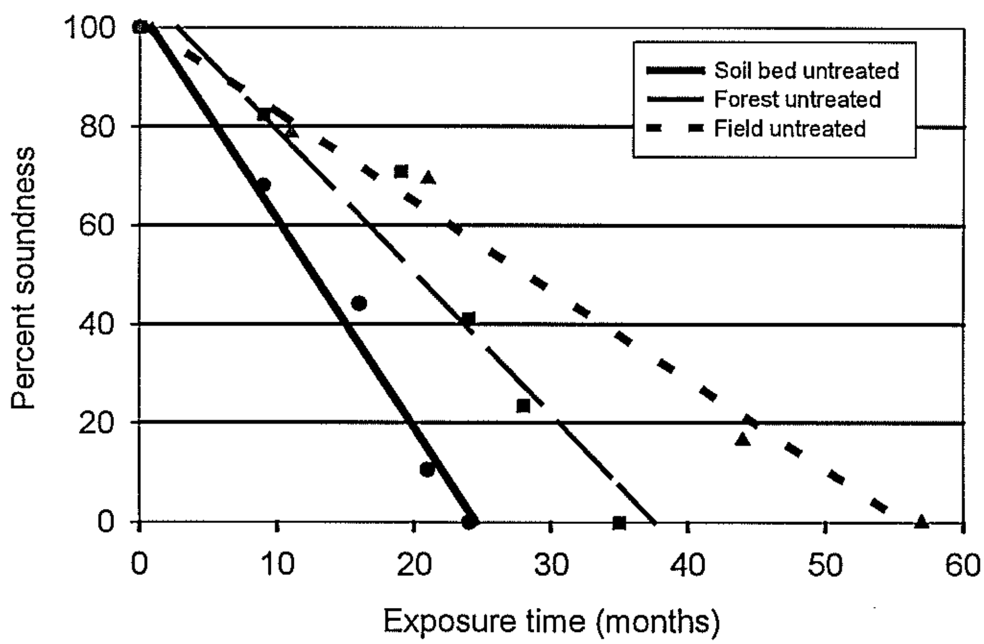


Figure 5: Comparison of decay rates CCA-C 2kg/m^3 retention

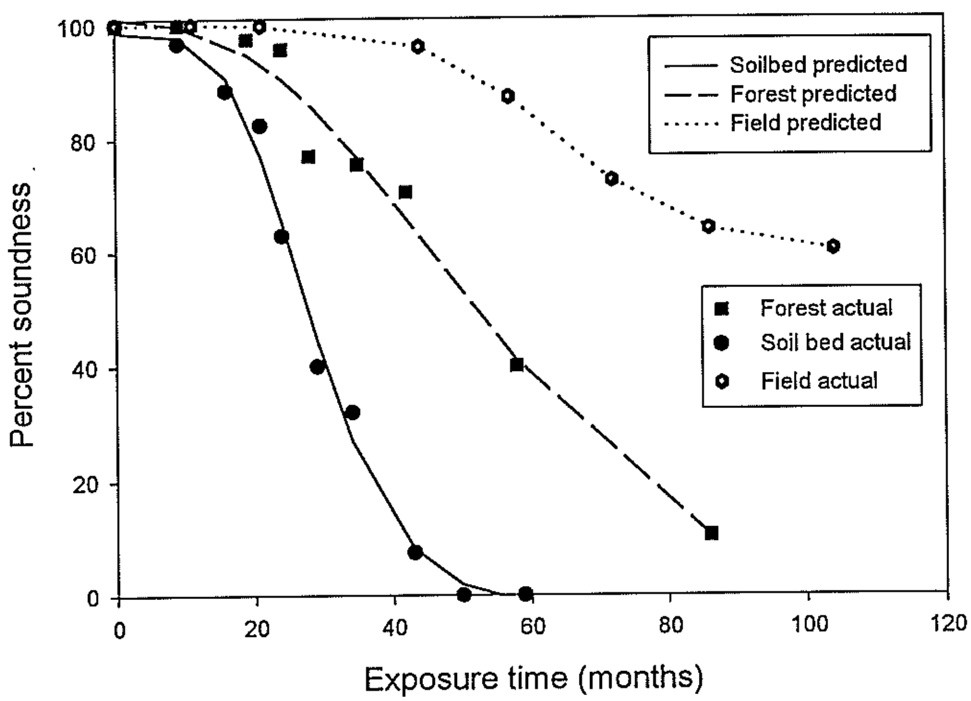


Figure 6: Ground contact performance Harrisburg Forest site CCA-C treated 5 x 19 x 200mm southern yellow pine stakelets

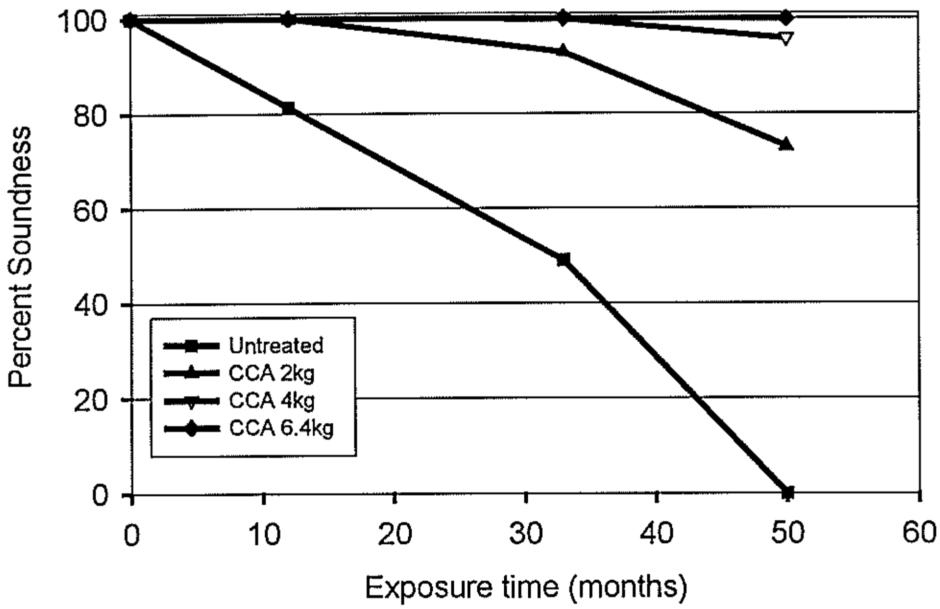


Figure 7: Soil bed performance CCA-C treated 5 x 19 x 200 mm southern yellow pine stakelets

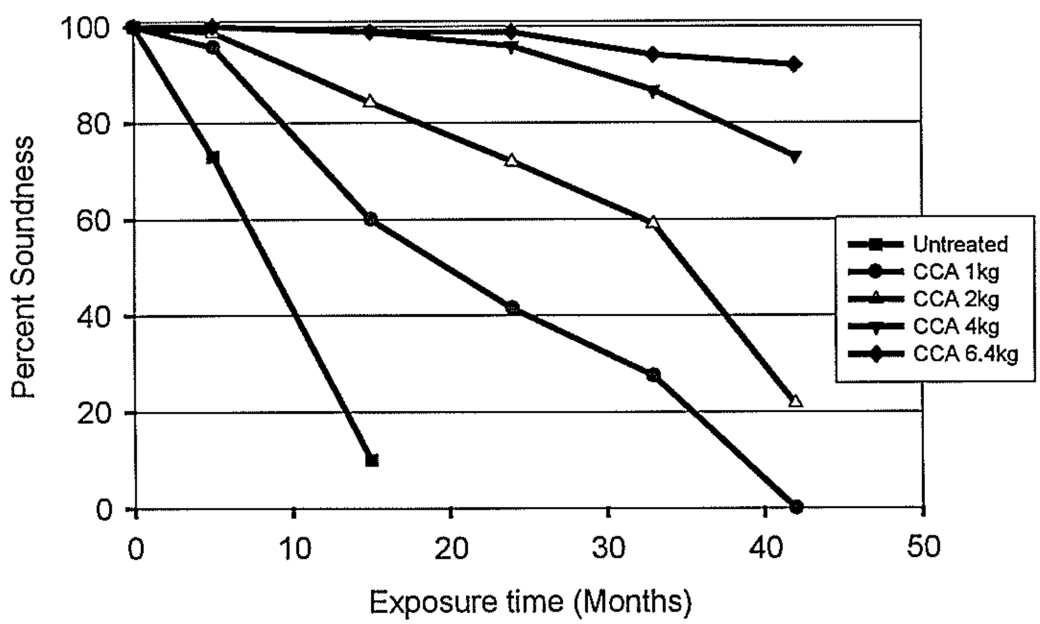
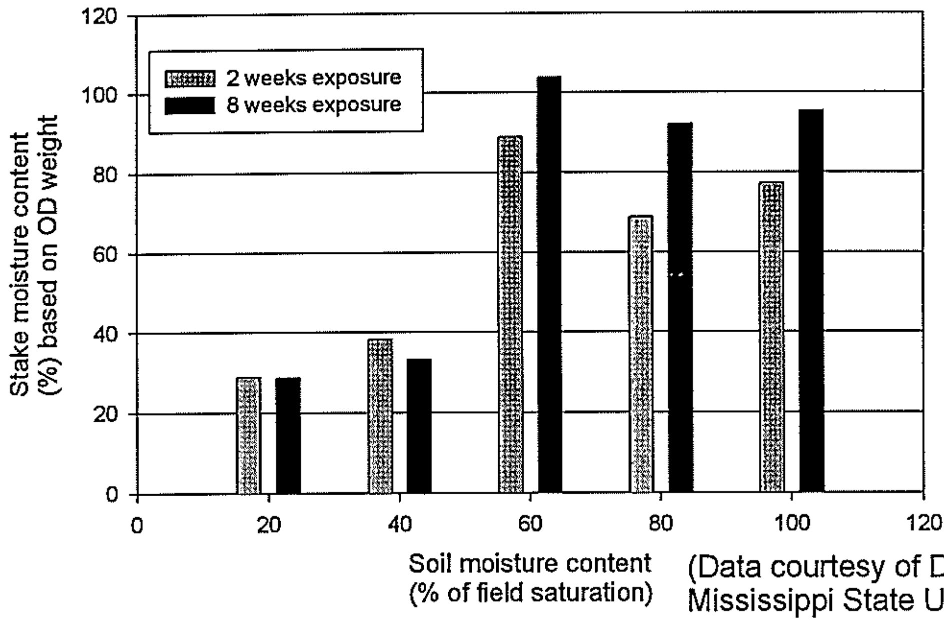


Figure 8: Soil moisture and its influence on stake moisture content

(A) Untreated southern yellow pine



(Data courtesy of D. Nicholas Mississippi State University)

(B) CCA treated southern yellow pine 6.4kg/m^3 retention

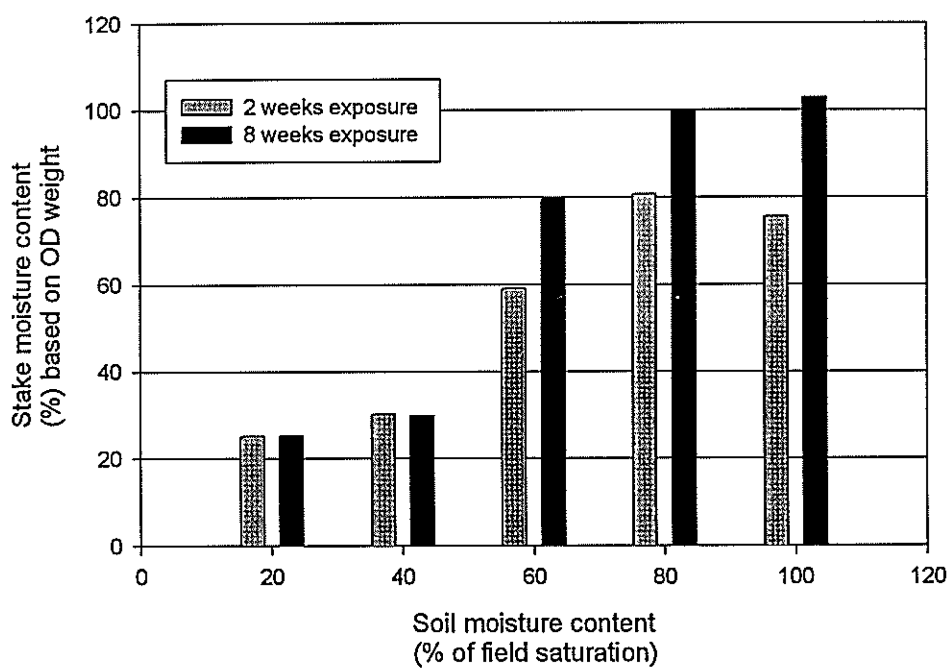


Figure 9: Depletion of CCA-C from southern pine stakelets (5 x 19 x 200 mm) 4kg/m3 initial retention, 12 months exposure. Natural soil and modified soil