The effect of surface fires on three species of hardwood tree seedlings

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Christianson, John D. (Wagner College, Staten Island, N.Y.) The effect of surface fires on three species of hardwood tree seedlings. Hutcheson Memorial Forest Bull. 2(4): 1-5. 1971.—Based on experimental litter burning in plantations of three species of hardwood seedlings, lower survival occurs following spring fires than following autumn fires. Red oak (*Quercus rubra*) seedlings were found to be more tolerant to fires, due to their resilience, than were sugar maple (*Acer saccharum*) and white ash (*Fraxinus americana*). White ash was found to be intolerant to fire and did not sprout readily. Sugar maple was intermediate of the three species in fire resistance.

This study was conducted to test the effects of surface fires on selected New Jersey hardwood tree seedlings. Three main effects were examined: the differences among species' ability to tolerate fire, the differences in the resprouting ability of the species following fire, and the resilience of the species following fire. It was clear that such a study was needed to test the hypothesis that fires have had a selective effect on the composition of the hardwood forests of the northeast.

Little experimentation has been reported on the tolerance of hardwood seedlings to fire. The tolerance to heat from sunlight and other sources has been reported by some investigators (Roeser, 1932; Shirley, 1936; Lorenz, 1939).

The sprouting of oak following fire and other disturbances is common knowledge and has been noted by many in the literature (Bromley, 1935; Cheyney, 1942; Hough and Forbes, 1943; Bourdau, 1954; Collins, 1956). Bourdeau (1954) found that of six oak species studied, all resprouted equally well.

There are conflicting statements on resistance of sugar maple to fire. Cheyney (1942) stated that sugar maple was extremely susceptible to injury from fire, that a light ground fire often killed it to the ground, and that it was also sensitive to injury by gas and smoke. However, he listed no references or evidence to support his view. Pinchot (1908) stated that sugar maple is fairly resistant to fire, but also failed to give evidence for this statement. Cheyney (1942) said white ash, because of its thin bark, is very susceptible to fire injury when young.

To measure the temperature of the fire several methods have been employed. Tempil° pellets (Silen, 1956; Fenner and Bentley, 1960) and seger cones (Nelson and Simes, 1934) have been used which are designed to melt at various temperatures, thus yielding only the maximum temperatures reached during a fire. Other methods have been employed, each with limitations, such as maximum thermometers (Korstian, 1927) and metal alloys, suitable for temperatures below 6009C (Nelson and Simes, 1934).

Thermocouples were the most useful instruments for measuring the temperature, since they give the duration of the temperatures as well as the extreme reached during the fire. They have been used by many investigators (Korstian, 1927; Heyward, 1938; Hare, 1965; Kayll, 1966; Gill and Ashton, 1968; Vines, 1968).

METHODS

The experiment was conducted on seedlings which had been planted on 64 plots at Hutcheson Memorial Forest, near East Millstone, New Jersey. Each plot, originally had five seedlings each, of five species: white pine *(Pinus strobus)*, white ash *(Fraxinus americana)*, sugar maple *(Acer saccharum)*, red oak *(Quercus rubra)*, and white oak *(Quercus alba)*. All trees were originally spaced at three foot intervals within each plot, and randomly distributed as far as the five species were concerned. The seedlings were from two to four years old when planted in 1964. When the author initiated this study in 1967, there were only three species with adequate numbers surviving: white ash, sugar maple, and red oak. The sugar maple seedlings were limited in number or absent on many of the plots.

The original design was to burn twenty plots, five on each of two spring dates, and five on each of two autumn dates. Five plots were to be left during each season to serve as controls. This design was followed in 1967; but in 1968 no burns were carried out, and in the spring of 1969 only 13 plots were burned.

There was then a total of 33 plots which received burns and 10 plots which served as controls. The treatment for each of the plots was randomly selected.

The seedlings had been planted on a recently plowed old field. Before each fire the grass and other herbaceous material that had developed were removed and replaced with oak leaf litter.

Various methods were used in attempting to measure the temperature of the fire. Before the spring fires of 1967, Tempil° pellets were suspended three inches over the litter on wire. The pellets proved unsatisfactory for measuring the temperature of the fire. Tempilaq°, a substance which can be painted on surfaces and melts at specific temperatures, was then used on ceramic tiles placed vertically on the litter before the autumn fires. This method also produced measurements which were found to be unrealistic for temperatures expected from fires of this type. In the spring of 1969, chromel-alumel thermocouples were used; and the temperatures and duration of temperatures were recorded on Rustrak recorders. This method yielded readings comparable to those found in earlier investigations (Korstian, 1927; Martin and Davis, 1961).

1971. William L. Hutcheson Memorial Forest Bulletin 2(4):1-5.

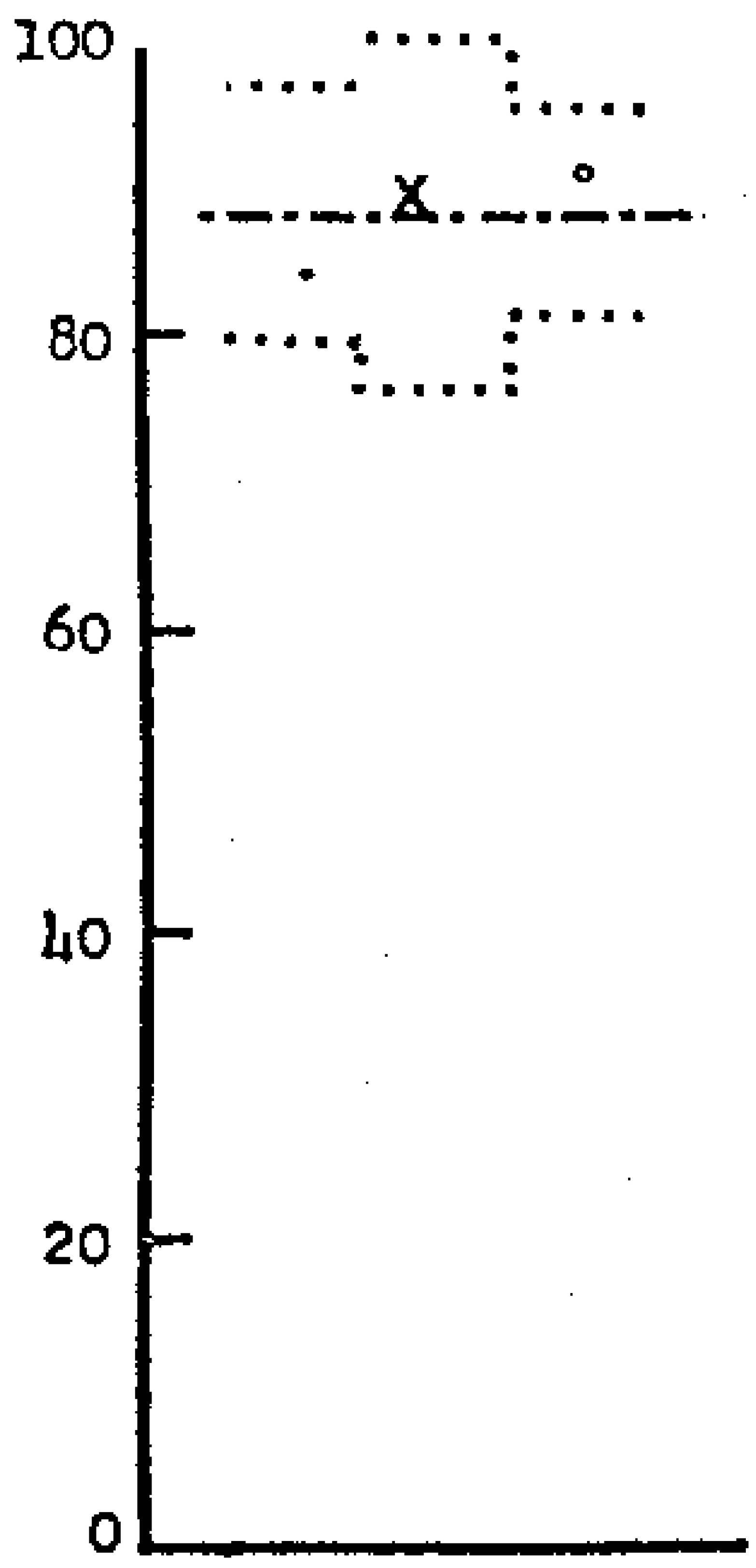

Fig. 1a

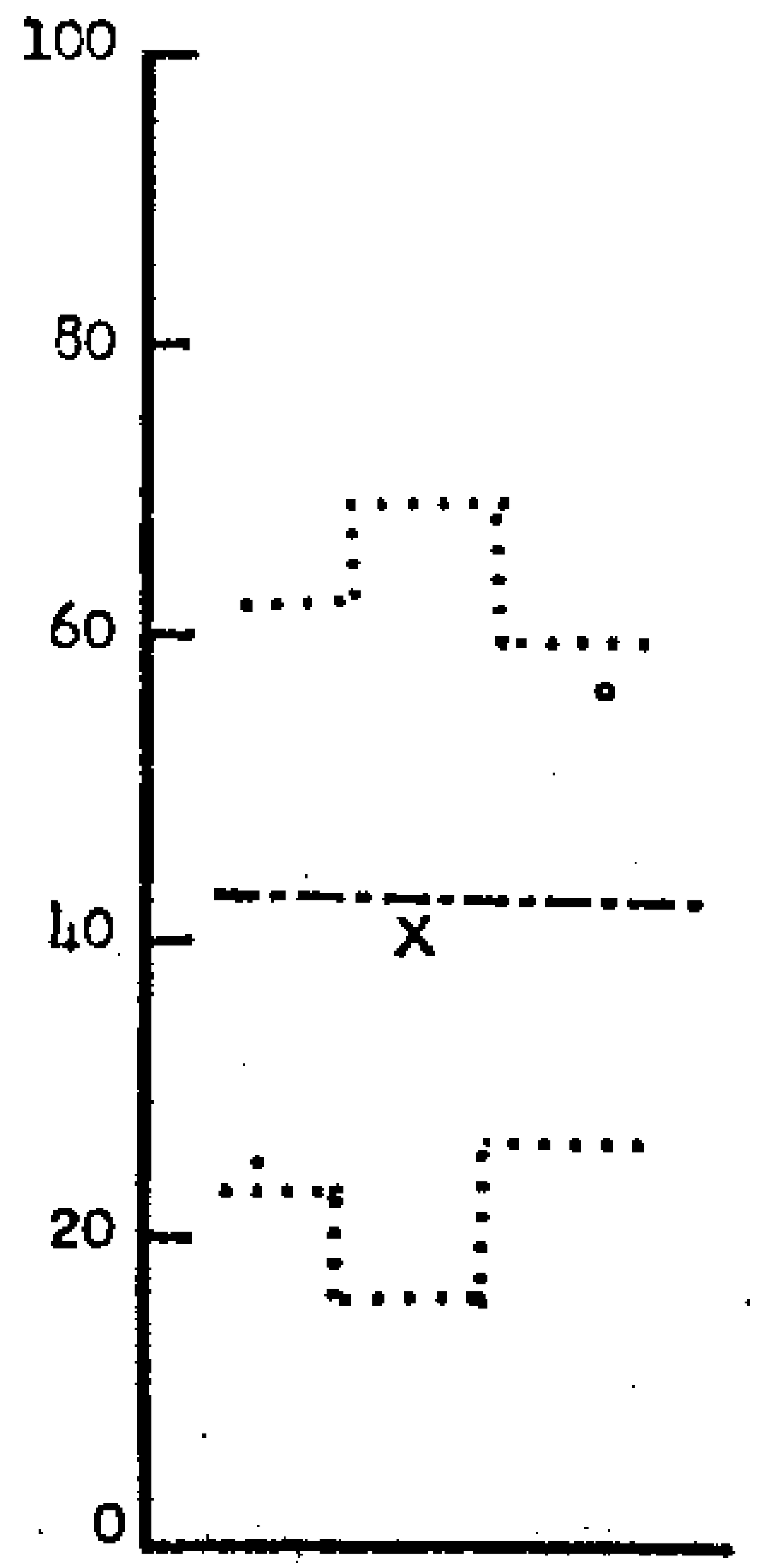

Fig. 1b

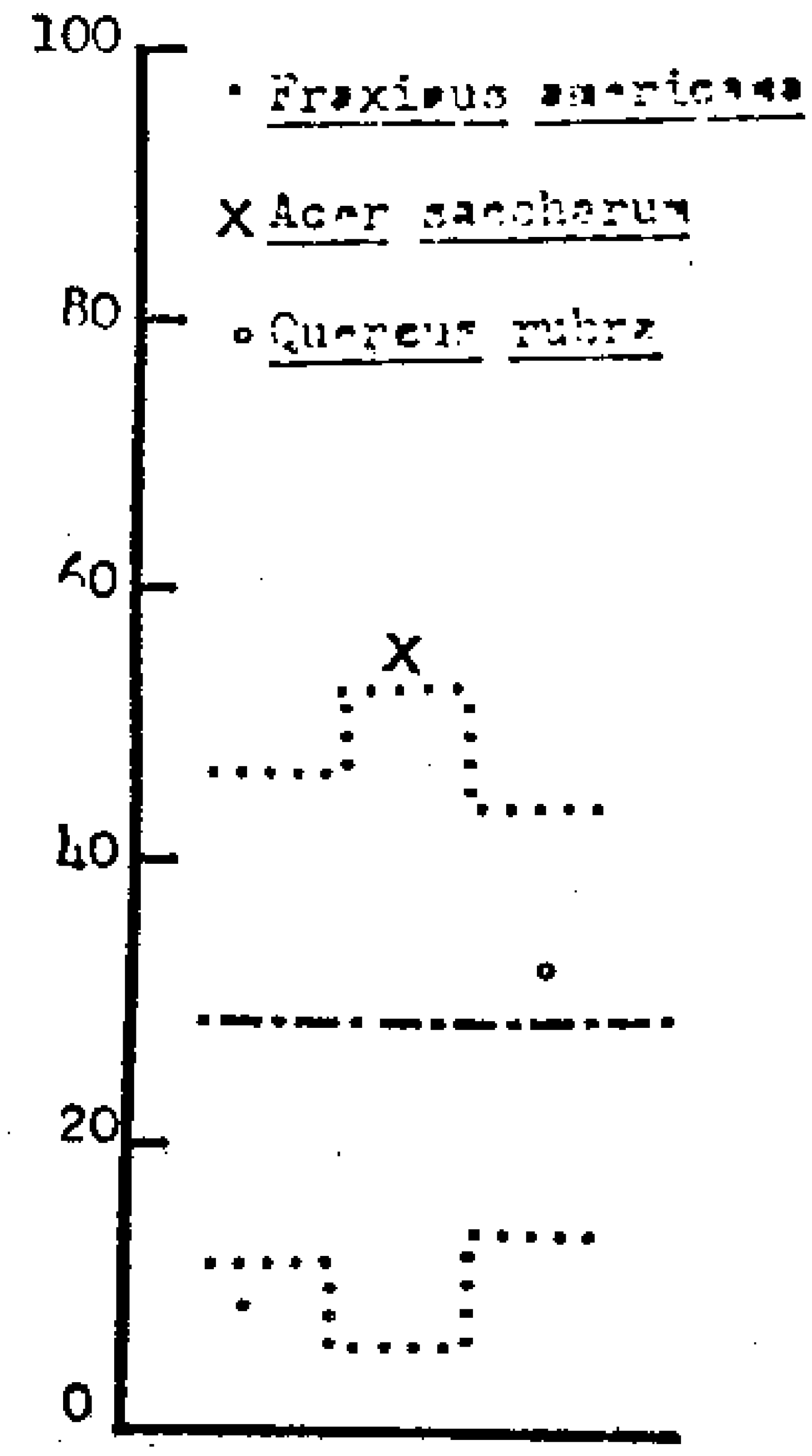

Fig. 1c

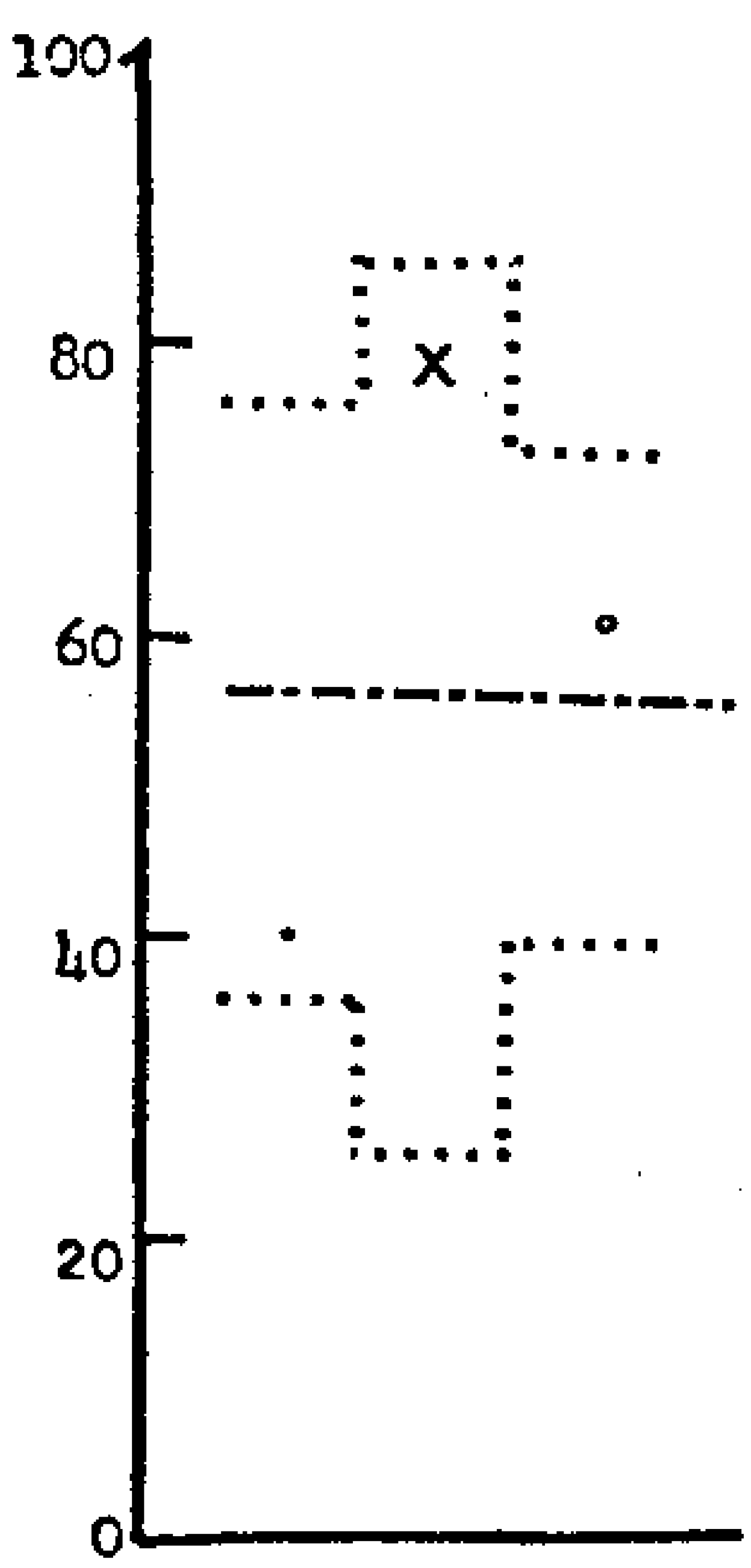

Fig. 1d

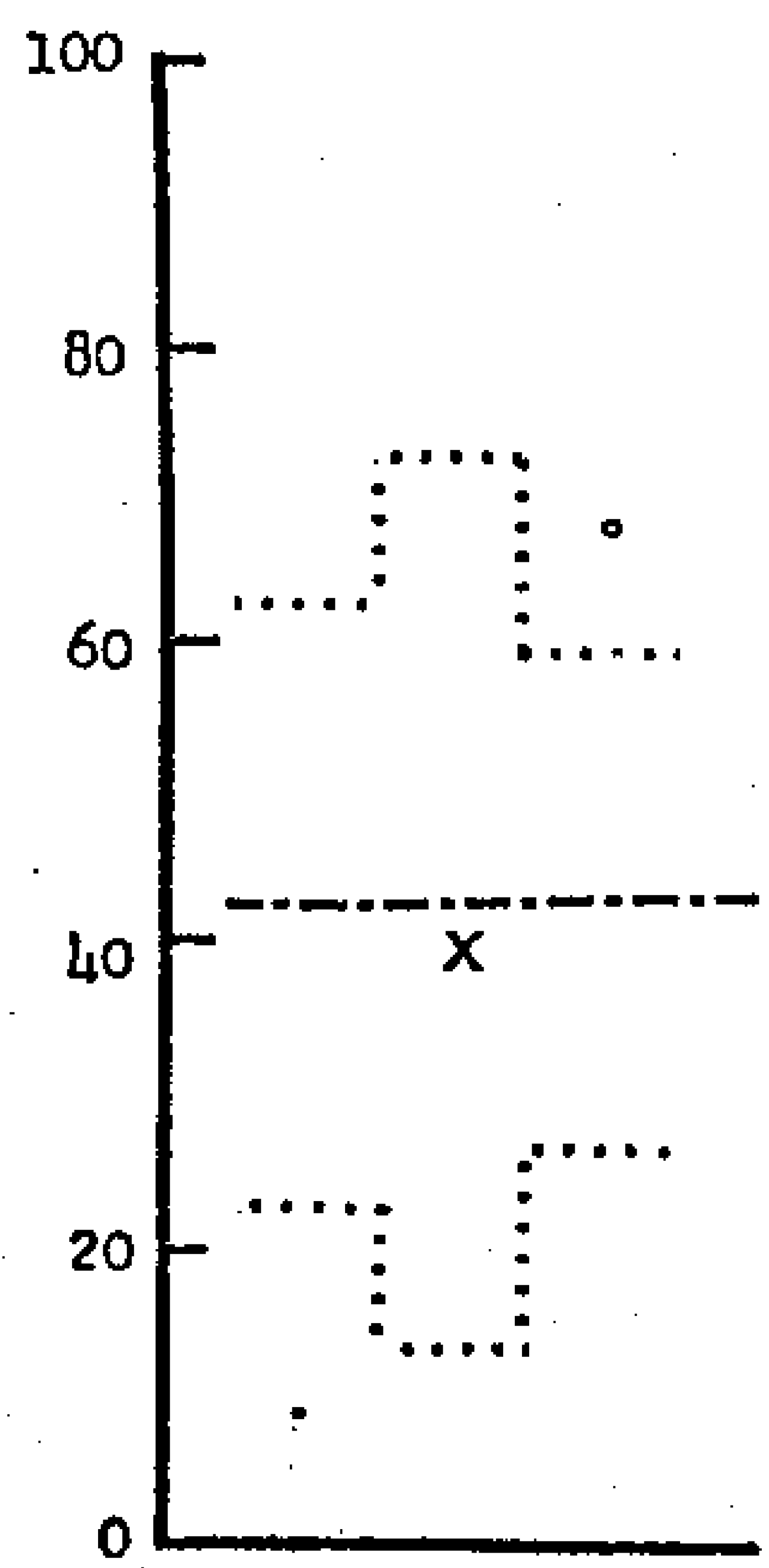

Fig. 1e

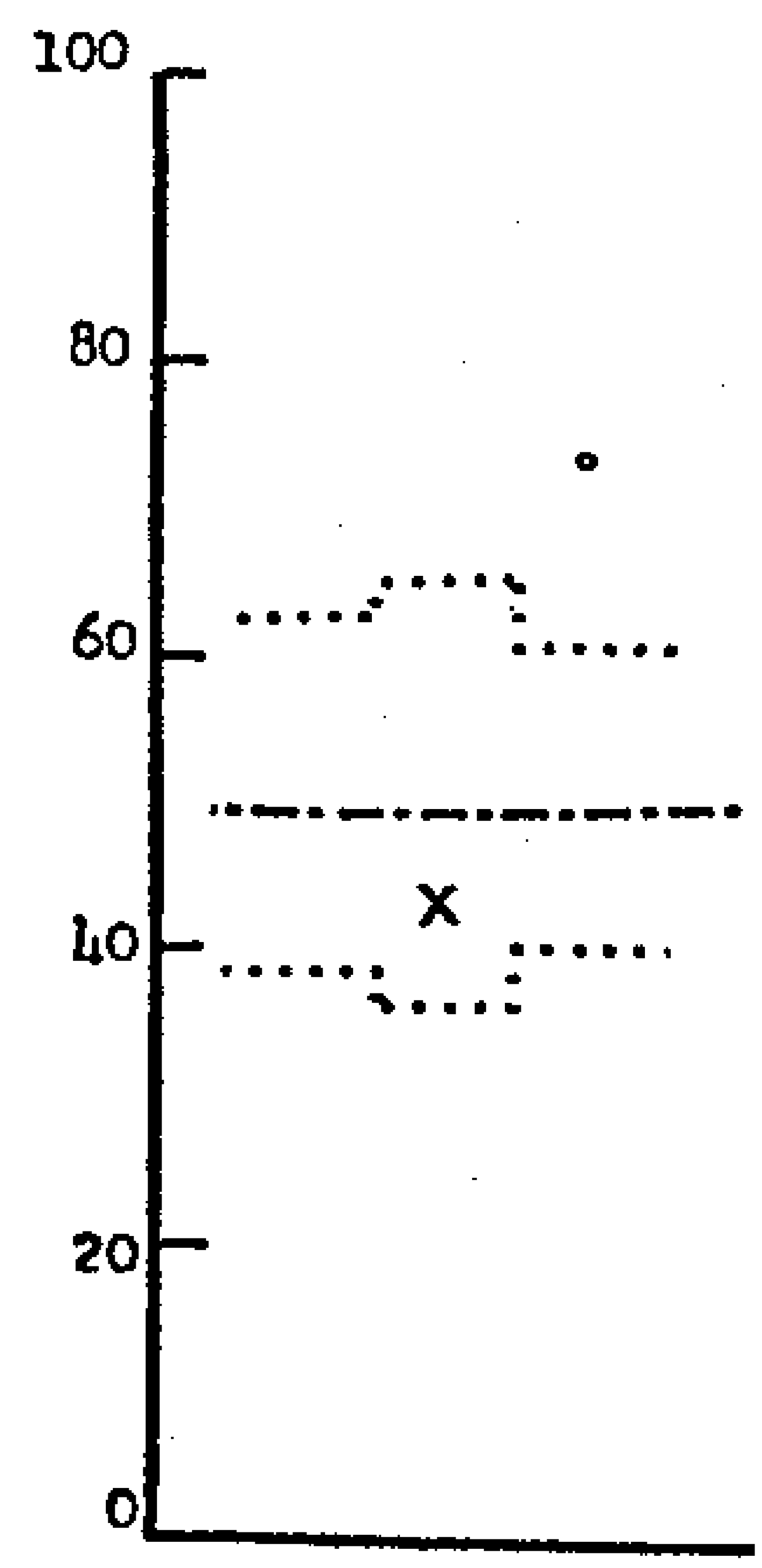

Fig. 1f

Figure 1. Graphical analysis of the percentage means of seedlings surviving the various treatments. The upper and lower decision lines are at the 0.05 level and vary in distance from the grand mean because of unequal numbers within the sample means. Figure 1a. Control treatments 1967. Figure 1b. First spring burn 1967. Figure 1c. Second spring burn 1967. Figure 1d. First autumn burn 1967. Figure 1e. Second autumn burn 1967. Figure 1f. Spring burn 1969.

The original height of the seedlings, except of those burned in the spring of 1967, was measured to the nearest centimeter. This was done to detect any differences that might have existed among the different size classes of seedlings.

Head fires were used for all treatments and the following factors were recorded on the day of the burn: moisture content of the litter, air temperature, relative humidity, wind speed and direction, and the time of day.

After each fire the following measurements were taken: the number of seedlings of each species which survived the fire uninjured, the number of seedlings which were killed (failed to leaf out), the number of seedlings which resprouted, and the size class of the seedlings which survived.

Data were collected in the summers of 1967 and 1968 on the plots burned in 1967. In the spring of 1969 all 43 plots were resampled when the data differed only slightly from that collected during the two previous summers. The data used in computing means and other values in this publication are those from the spring in 1969.

The data were analyzed primarily by the statistical method of analysis of means (Halperin, 1955). Chi square was also used to test differences between observed and theoretical values.

RESULTS

Using the calculated upper and lower decision lines for each of the individual treatments, various significant differences were found in the survival value of the seedlings (Fig. 1). There were no significant differences found among the survival values of the species within the ten control plots (Fig. 1a). The first spring treatment with fire (Fig. 1b) showed that the mean survival rates of the species were not significantly different. Red oak approached the upper limits and white ash the lower limits, at the 0.05 probability level. The second spring burn (Fig. 1c) was the only instance where sugar maple seedlings had a significantly higher survival rate than the grand mean. White ash seedlings were significantly less able to survive following the second spring burn.

The first autumn fire showed none of the species to differ significantly from the grand mean (Fig. 1d). A significantly greater survival rate of red oak seedlings than the average was found following the late autumn fire (Fig. 1e). White ash seedlings again had a significantly lower survival rate than the grand mean. Similar results occurred following the spring fire of 1969 (Fig. 1f), where red oak survival was significantly higher than the mean and white ash significantly lower than the mean percentage of seedlings surviving.

White ash seedlings had a lower survival following each of the fires than the other two species. The percentage of red oak seedlings surviving after the fires was greater than the mean value for each of the five fires. Survival rate of sugar maple seedlings only twice exceeded the mean percentage of survival.

The mean percentage of seedlings resprouting were plotted for each of the species following the fires (Fig. 2-3). Red oak seedlings resprouted significantly more

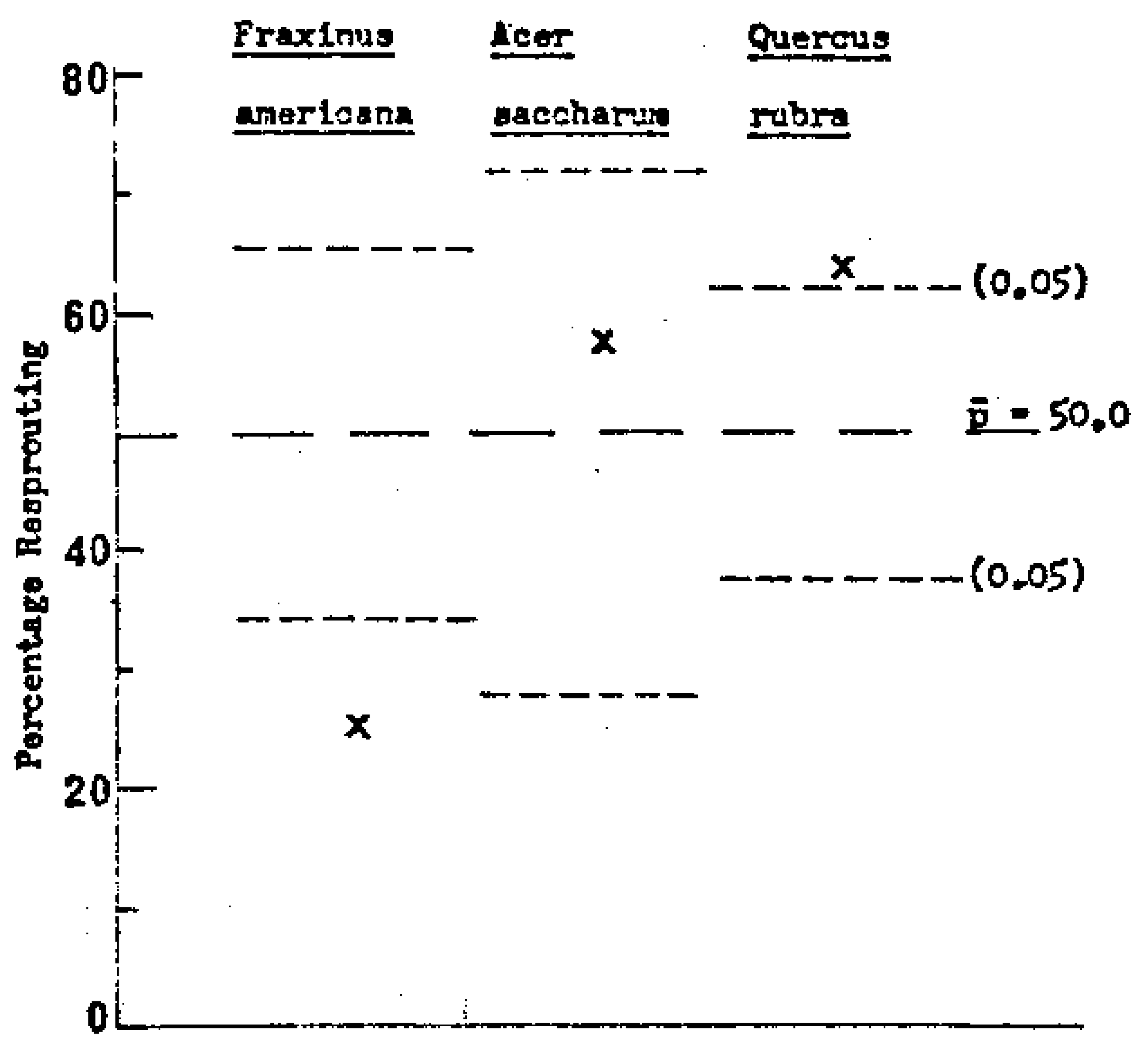

Figure 2. The percentage of seedlings resprouting plotted around the grand mean and the upper and lower decision limits (at the 0.05 level) of each species, for the autumn 1967 treatment.

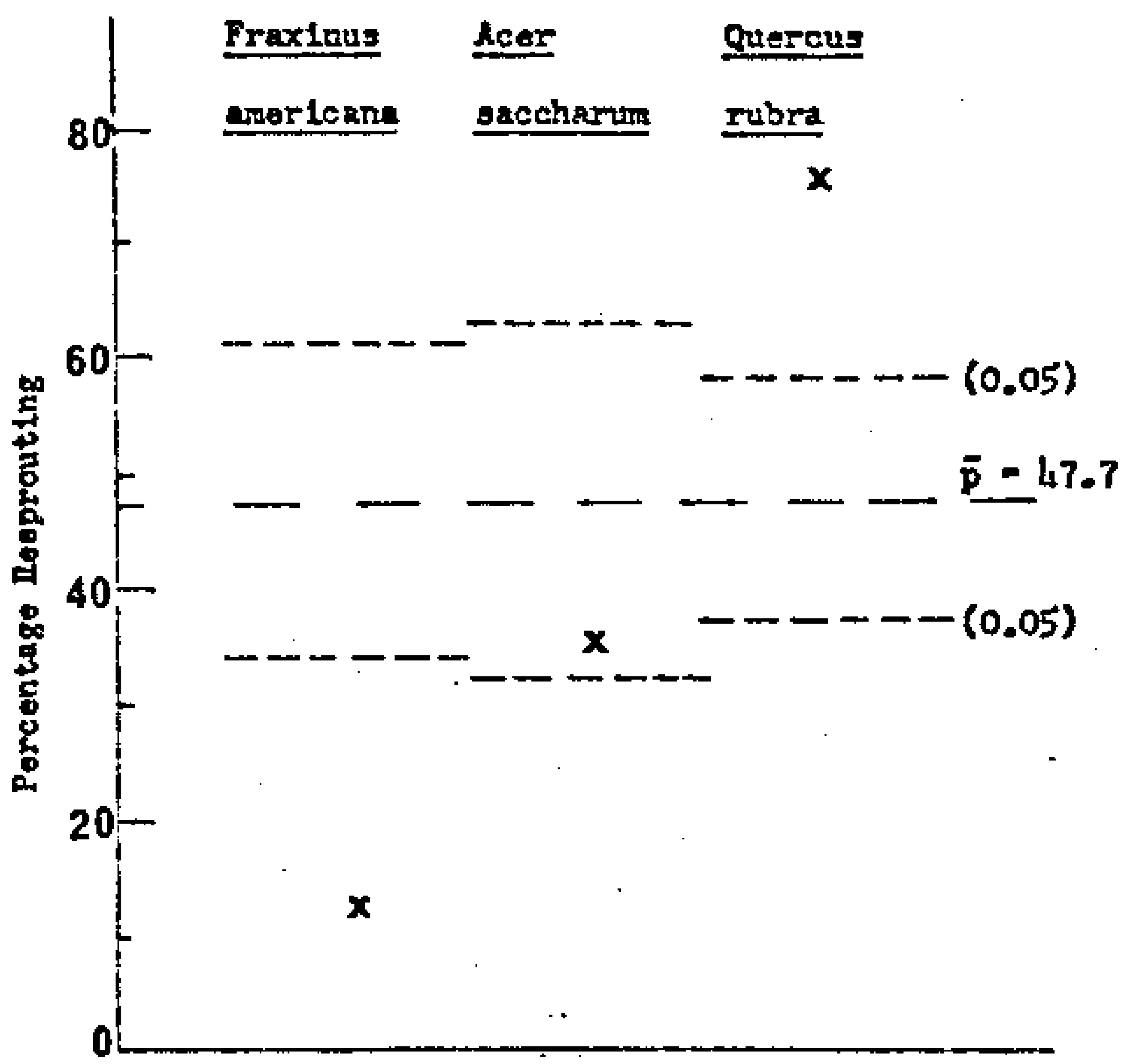

Figure 3. The percentage of seedlings resprouting plotted around the grand mean and the upper and lower decision limits (at the 0.05 level) of each species, for the spring 1969 treatment.

than the average for all seedlings following the fires. White ash seedlings were found to resprout significantly less, at the 0.05 probability level, following each of the fires than the average. Resprouting of sugar maple seedlings did not differ significantly from the mean percentage of seedlings resprouting.

The size of the seedlings differed greatly, not only among species but also within each species. The seedlings of white ash were the largest, averaging approximately 100 cm in height, while those of sugar maple were approximately 80 cm and those of red oak were approximately 55 cm. The size class within the species yielded little information as to the effects of size on survival rate. Large seedlings were killed in many instances, when small seedlings survived.

DISCUSSION AND CONCLUSIONS

Evidence is presented that hardwood tree species do differ in fire tolerance. Survival is partly due to species' ability to resprout (Fig. 3). Significantly greater percentages of red oak seedlings survived the fires than the mean survival of the three species studied (Fig. 4). Red oak seedlings were smaller than the other seedlings in the research, yet had a higher survival rate. White ash seedlings showed a significantly lower percentage of survival at the 0.01 level, with only 23% surviving. Chi square used to test the variability of the actual number of seedlings surviving against the theoretical number produced a value significant at the 0.01 probability level, which was primarily due to the differences between the observed and theoretical values for white ash and red oak. The

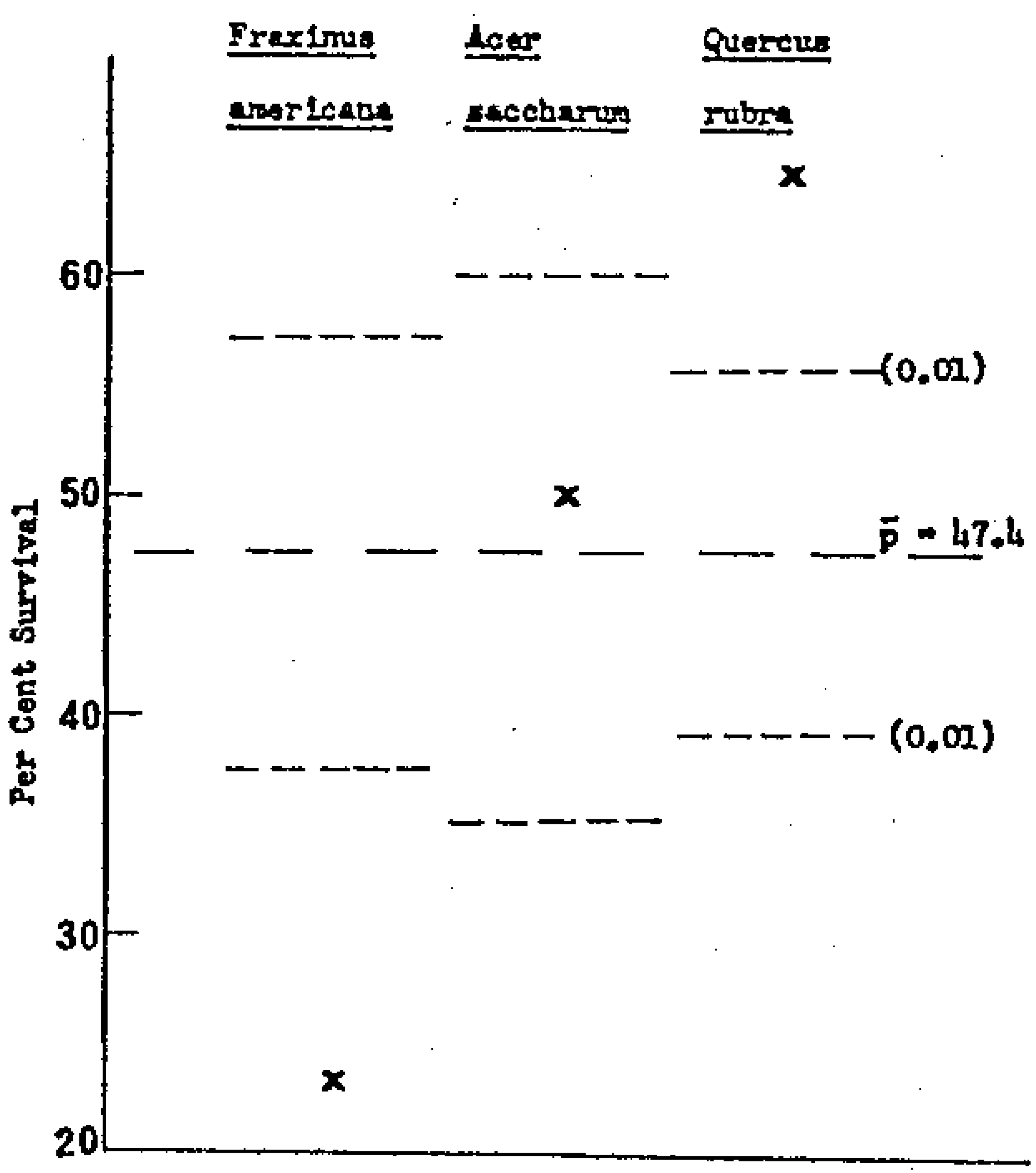

Figure 4. Graphical analysis of the means for the percentage of seedlings surviving all fire treatments, by species.

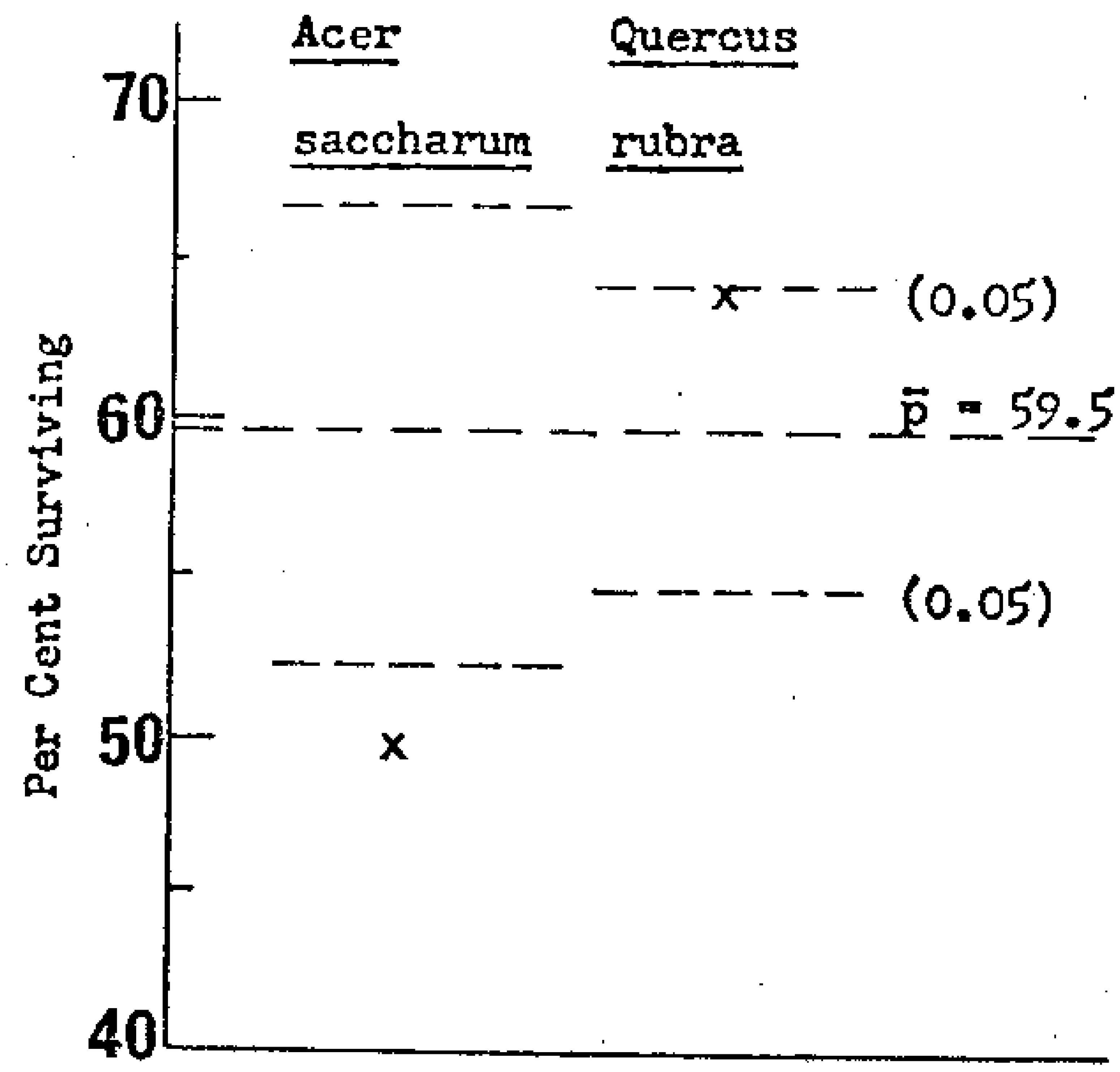

Figure 5. Analysis of means for sugar maple *(Acer saccharum)* and red oak *(Quercus rubra)* seedlings surviving all fire treatment.

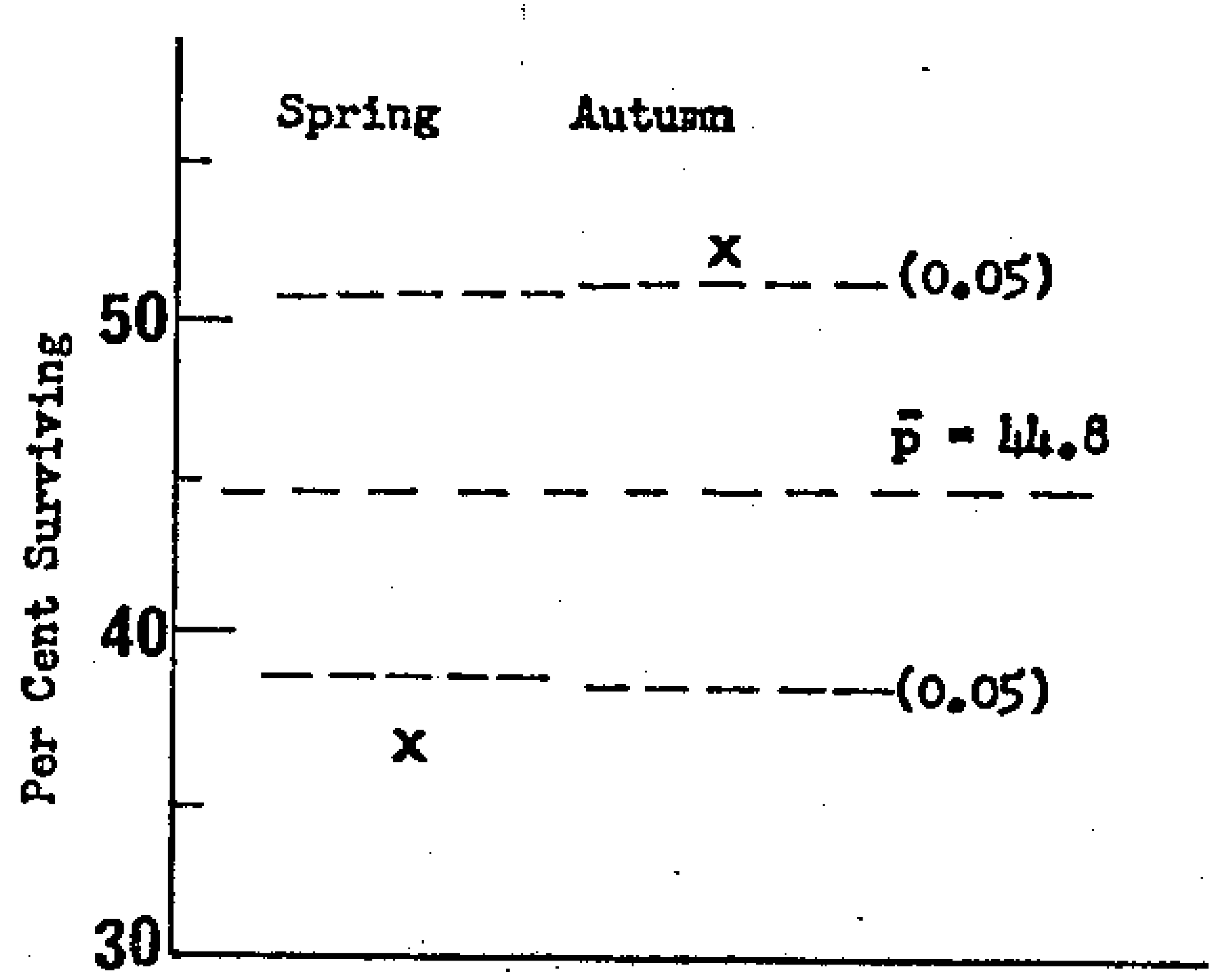

Figure 6. Analysis of means for the percentage of seedlings, of all species, surviving the fire treatments, by seasons.

white ash had a much lower number of seedlings surviving than expected. and the red oak had a higher number surviving.

Since one of the main objectives of this study was to determine the differences between the tolerance of red oak and sugar maple seedlings, decision limits were plotted around the mean percentage of seedlings of these species which survived (Fig. 5). This illustrates that sugar maple seedlings had a significantly lower survival rate, at the 0.05 probability level, than the grand mean.

Seasonal differences were analyzed between the spring and autumn fires of 1967 (Fig. 6). Significantly more seedlings of all species survived the autumn treatments than the average of the two seasons. This difference may be attributed to environmental conditions during the fire. There may also be physiological differences in the plants during the different seasons which may also contribute to the significant differences in fire tolerance during different seasons.

Time-temperature measurements were obtained from only thirteen of the thirty-three plots burned. Little correlation could be found between the percentage of seedlings surviving and the mean maximum temperature reached on each plot or between survival and the duration of temperatures exceeding the lethal temperature of 60° C. The poor correlation which was found can only be explained by stating that the measurements on each plot were only replicated three times, and that due to high variability of temperatures during fires it is difficult to obtain good estimates of the conditions which are present during a fire. The highest survival rate was found on the plot which had the lowest maximum temperature and the shortest duration.

In conclusion, lower survival was found following spring fires than following autumn fires studied. Red oak *(Quercus rubra)* seedlings were more tolerant to fire, due to the resilience, than were sugar maple *(Acer saccharum)* and white ash *(Fraxinus americana)*. White ash was very intolerant to fire and did not sprout readily. Sugar maple was intermediate of the three species in fire resistance.

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