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Seasonal Changes in Carbohydrates and Ascorbic Acid of White Pine and Possible Relation to Tipburn Sensitivity

Abstract. — Changes in amounts of total soluble carbohydrates and ascorbic acid were related to needle length of eastern white pine during June and July 1967 at Bent Creek Experimental Forest. Sugar values remained low through the early growing season, and several instances of injury to clones sensitive to tipburn occurred as late as mid-July. Sugar levels fluctuated somewhat, increasing during fair weather and decreasing during cloudy weather. Ascorbic acid levels increased more regularly as the needles matured and with less short-term fluctuation than did soluble carbohydrates. The relatively low carbohydrate content may have been indicative of a slow maturation of needle tissues, which may be related to a prolonged sensitivity to air pollutants. If so, the amount of soluble carbohydrates or ascorbic acid may be more meaningful than needle length as an indication of needle maturity.

Emergence tipburn, a needle blight of eastern white pine (*Pinus strobus* L.), is characterized by a dying of the tips of young: elongating needles in June or July. Susceptibility to the disease is therefore a seasonal phenomenon and is probably reiated to maturity of needie tissue. This syndrome of pines apparently is caused by ozone, or possibiy some other oxidant in the atmosphere (Berry and Ripperton 1963). Ozone injury to lesser plants has been observed by a number of investigators, and the sensitivity of severai species to ozone seems to be related to the ievel of soluble sugars or ascorbic acid in the leaves (Rich 1964; Menser 1964).

Since the early-season sensitivity of white pine to air pollutants has been well established, we wished to study the leveie of soluble sugars and ascorbic acid in the needles during this most sensitive period. We wished to see if there were any seasonal changes in these plant constituents which might suggest a reiationship to changes in tipburn sensitivity.

Studies were conducted in 1966 at Duke University, Durham, North Carolina, and in 1967 at Bent Creek Experimental Forest near Asheville, North Carolina.[1] Very little air pollution injury to plants has beer. noted in the Durham area, while air pollution injury, such as emergence tipburn, occurs rather frequently at the Bent Creek location.

Four 'i-year-old trees were sampled at Durham: and two ramets each of four clones (two susceptible to tipburn and two resistant) of 6-year-old grafts were used at Bent Creek. Duplicate samples of needies were collected at 0800 hours from the middle of current flushes on branches which first elongated 2 years previousiy. All analyses were made on fresh needles. Solubie carbohydrates were measured in 80-percent ethanoi extracts which had been treated with activated charcoal. Total solubie carbohydrates were determined by the method outlined by Nalewaja and Smith (1963) and reducing sugars by the method outlined by Neison (1944). Ascorbic acid was measured in trichloroacetic acid extracts essentially as described by Freebairn (1959). Needle lengths were measured on each sampling date.

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Total carbohydrate contents at Durham (fig. 1) increased roughly in the same pattern as did needle lengths. Reducing sugar values were more variable, but they did show a general increase as the season advanced. Ascorbic acid changes were not determined.

At Rent Creek (fig. 2) needle length increased regularly from early June to mid-July. Total carbohydrate levels, however, remained about constant until the end of June, with the only conspicuous increase occurring early in July. Reducing sugars remained essentially unchanged over the sampling period. Ascorbic acid levels increased over the period except for a slight decrease by mid-July.

The reasons for the differences in sugar trends at the two locations are not clear, although differences in climate and weather

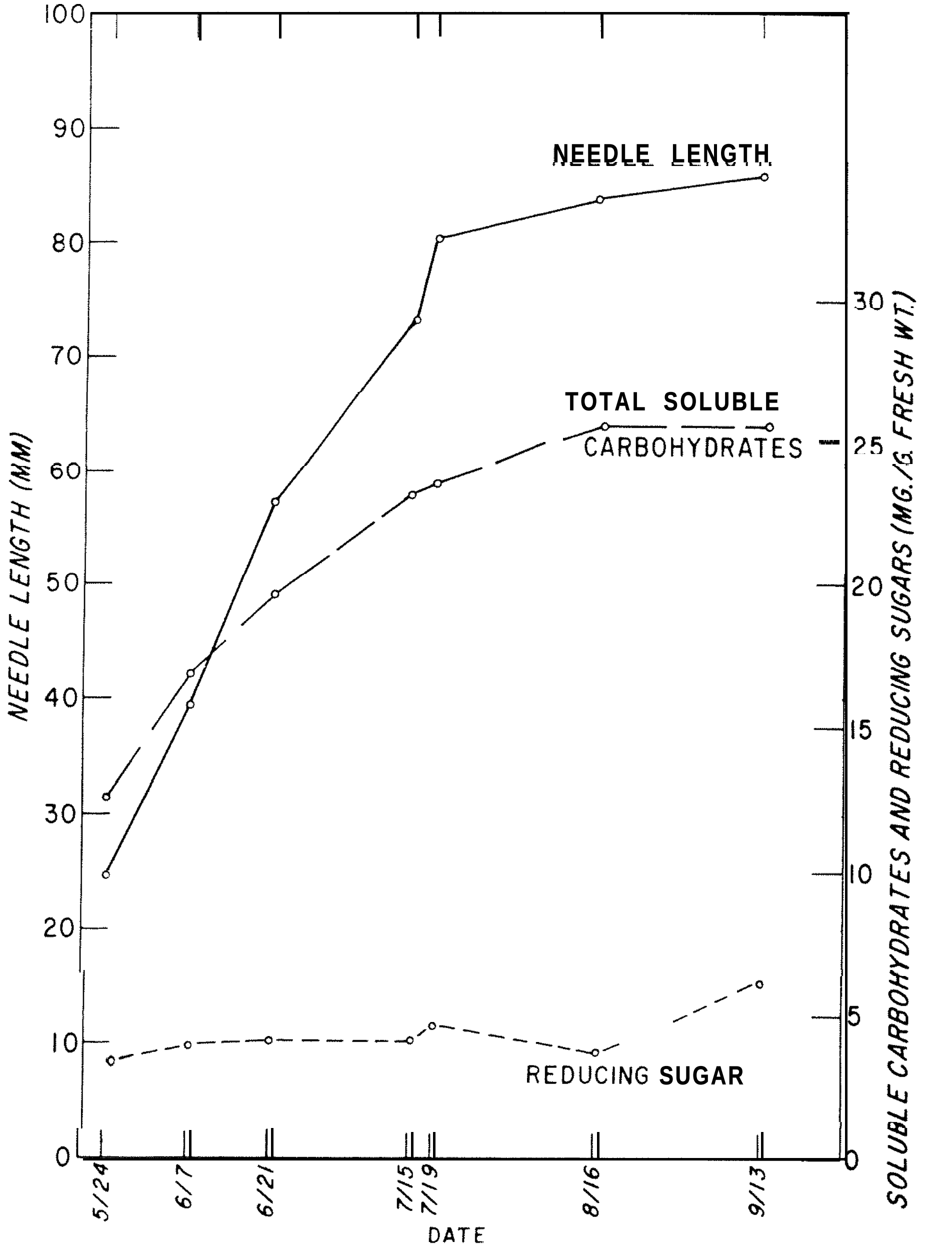

Figure 1. — Seasonal growth and levels of total soluble carbohydrates and reducing sugars in white pine needles from Durham (1966).

are probably involved. Bent Creek has a cooler climate than Durham, and the weather during the sampling period at Bent Creek in 1967 was much more variable than at Durham in 1966. A number of periods of cool, cloudy, and rainy weather occurred during the early summer at Bent Creek; this was not the case at Durham. Supplemental studies at Bent Creek indicated that levels of carbohydrates in needles tended to increase during fair weather, while they were relatively low after a cloudy period. This trend was more apparent for the reducing sugars than for total soluble carbohydrates. Because pertinent weather data were not collected, however, conclusions regarding the effect of short-term weather condition? on carbohydrate levels in white pine needles cannot be drawn at this time.

Additional data on soluble carbohydrate levels were collected through the fall and winter at Durham. Total carbohydrates increased to a maximum of 50.1 mg./g. fresh weight in January and subsequently declined to 35.2 mg./g. in May 1967. Reducing sugars peaked at 9.3 mg./g. fresh weight in February and declined to 5.4 mg./g. in May. The qualitative composition of the soluble carbohydrate fraction did not change greatly during the early growing season. Sucrose was always the most abundant sugar, with glucose and fructose contributing about equally to the

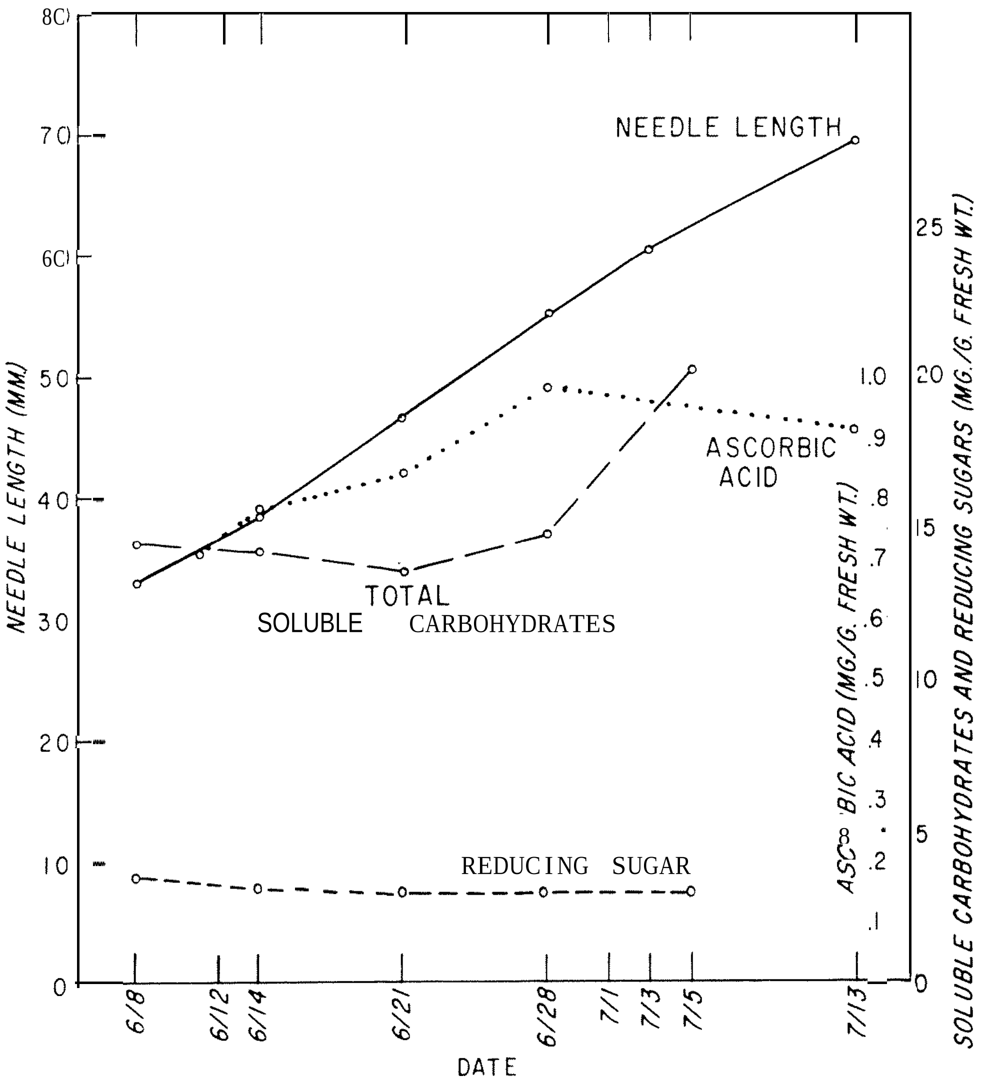

Figure 2. — Seasonal growth and levels of total soluble carbohydrates, ascorbic acid, and reducing sugars in white pine needles from Rent Creek (1967).

reducing sugar fraction. Traces of raffinose were present until the end of June. Raffinose later appeared again in October and increased in quantity until January. An increase of raffinose in the winter foliage of white pine has been noted previously by others (e.g., Parker 1959).

Seasonal samplings of ascorbic acid content were made only at Bent Creek, where ascorbic acid was found to increase more regularly than soluble carbohydrates. A series of daiiy samplings from a single tree showed that short-term fluctuations in ascorbic acid were much less pronounced than variations in sugar content. Ascorbic acid ieveis also probably continue to increase through the winter, because comparisons of new and i-vear-old needies at Durham in June 1966 showed 0.72 mg./g. fresh weight in new needies and 1.18 mg./g. in the older needies. Values as high as 1.87 mg./g. fresh weight have been found in routine anaiyses of second-year needles.

Although direct comparisons between the Durham and Bent Creek samplings cannot be drawn because they were done in different years, the differences in soluble carbohydrate trends at the two locations dc suggest an interesting possibility. At Durham, where soiuble carbohydrates increased regularly with needle length, no symptoms of tipburn were observed on any white pine trees. We do not know: however, whether high levels of ozone or other phytotoxicants occurred during the growing season or whether the trees observed in the Durham area are inherently insensitive to ozone. At Bent Creek: where sugar values remained low through the eariy growing season, there were severai instances of injury on known-sensitive clones from as early as the first week in June to as late as mid-July. Initiai injury typically occurred in a localized area about 15 to 20 mm. from the base of the needies. as described by Berry and Ripperton (1963) and Linzon (1960). We therefore consider it possible that soiuble carbohvdrate content may be a more meaningful indication of needie maturity than total needle iength, because the trends in these two measurements were so different at the two locations. We also suggest that the relatively low soluble carbohydrate contents at Bent Creek are an indication of a slower maturation of needle tissues and may be an indication of correspondingly greater sensitivity to air pollutants.

Ascorbic acid ieveis may also be useful in estimating stages of needie maturity. particularly in light of the fact that these ievels have fewer and iess pronounced short-term fluctuations than those that might occur with soiuble carbohydrates as a result of variations in diurnal weather and cloud cover.

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