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Abstract. Over three consecutive years in central Mississippi, sweetgum (*Liquidambar styraciflua* L.) and sycamore (*Platanus occidentalis* L.) fruits had nearly reached full-size by late June. Sweetgum seeds were physiologically mature by mid-August, but dry weight increased until late September. As sweetgum seeds matured, the crude fat level rose to 27 percent of seed dry weight. During maturation, concentrations of soluble nitrogen, soluble carbohydrates, and magnesium decreased, while those of protein nitrogen and phosphorus increased. Sycamore seeds became physiologically mature by early September. Chemical changes in sycamore were similar to those in sweetgum, except that the major food reserves were carbohydrates and not fats. ***Forest Sci. 18:223–231.***

Additional key words. *Liquidambar styraciflua, Platanus occidentalis,* chemical analysis.

KNOWLEDGE of the morphological, physiological, and chemical changes that take place as seeds grow and mature is necessary to improve seed technology. This paper reports results of 3 years' study on fruits and seeds of sweetgum (*Liquidambar styraciflua* L.) and American sycamore (*Platanus occidentalis* L.), two small-seeded hardwoods of great economic importance.

Sweetgum's unisexual flowers appear in March to May, depending on latitude and weather (Martindale 1965). The pistillate flowers are borne in axillary, globose heads which form the 1- to 1½-inch diameter multiple heads of small, two-celled fruits (Sargent 1965). As they mature in early fall, the beak-like capsules open to disperse the small, winged seeds. Average yields of 52 to 58 good seeds per fruit have been reported for central Mississippi sources Bonner 1967, Kearney and Bonner 1968).

Sweetgum seeds are slightly dormant and normally germinate rapidly after 2 to 4 weeks of cold, moist stratification (Bonner 1967). Seeds from the southern part of the range require less stratification than northern seeds (Wilcox 1968).

Sycamore's unisexual flowers also appear in March to May as the leaves unfold (Merz 1965, Sargent 1965). The pistillate head matures into a globose fruit 1 to 1½ inches in diameter. The seed is an elongated, single-seeded achene, about ⅜ inch long, with a hairy tuft at the base (Sargent 1965). The fruits remain on the trees throughout winter and gradually break up, dispersing the seeds. Average yields of 1700 seeds per fruit have been reported for Mississippi and Louisiana sources, but germination averaged only 46 percent (Briscoe 1969). Isolated trees may produce fruits with practically no filled seeds.

Sycamore seeds are not dormant, and stratification is not normally required for rapid germination (Bonner 1970b, Webb and Farmer 1968).

Procedure

Four seed-bearing trees of each species were selected near State College in east-central Mississippi. Beginning in the last week of June each year, 10 fruits were collected from each tree every 2 weeks until apparent maturity was reached on the trees in September or October. It was in-

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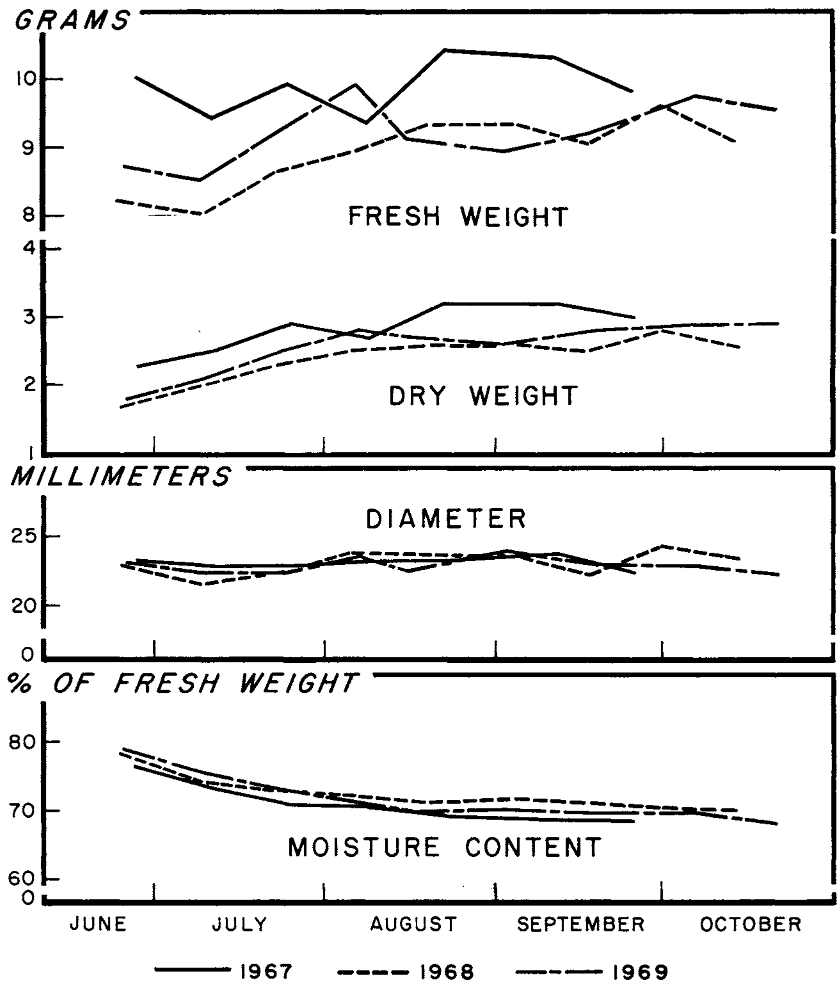

FIGURE 1. *Seasonal changes in fresh weight, dry weight, diameter, and moisture content of sweetgum fruit heads.*

tended to collect from the same trees each year, but a very light crop in 1968 and the cutting of one sweetgum sample tree forced some substitution. Only 5 fruits per tree were taken for each measurement in 1968. Data from two very good crop years were obtained for each species, however: 1967 and 1969 for sweetgum, and 1969 and 1970 for sycamore.

Fruits were collected in the morning and transported to the laboratory in polyethylene bags for measurement of fresh weight, diameter, and dry weight. Dry weights were obtained after 24 hr of drying at 105°C in a forced-draft oven. Moisture contents were expressed as percentages of fresh weights.

Dry weights of individual seeds of both species were determined for one tree in 1968 and two trees in 1969. A sample of 10 seeds was taken from a composite of seeds from all fruits that were dried in the oven. These seeds were dried for an additional 24 hr and reweighed. Specific gravity of individual fruits was measured by water displacement for selected trees in 1968 and 1969.

Extra fruits were collected from two trees starting in August each year to secure seeds for germination tests. These fruits were air-

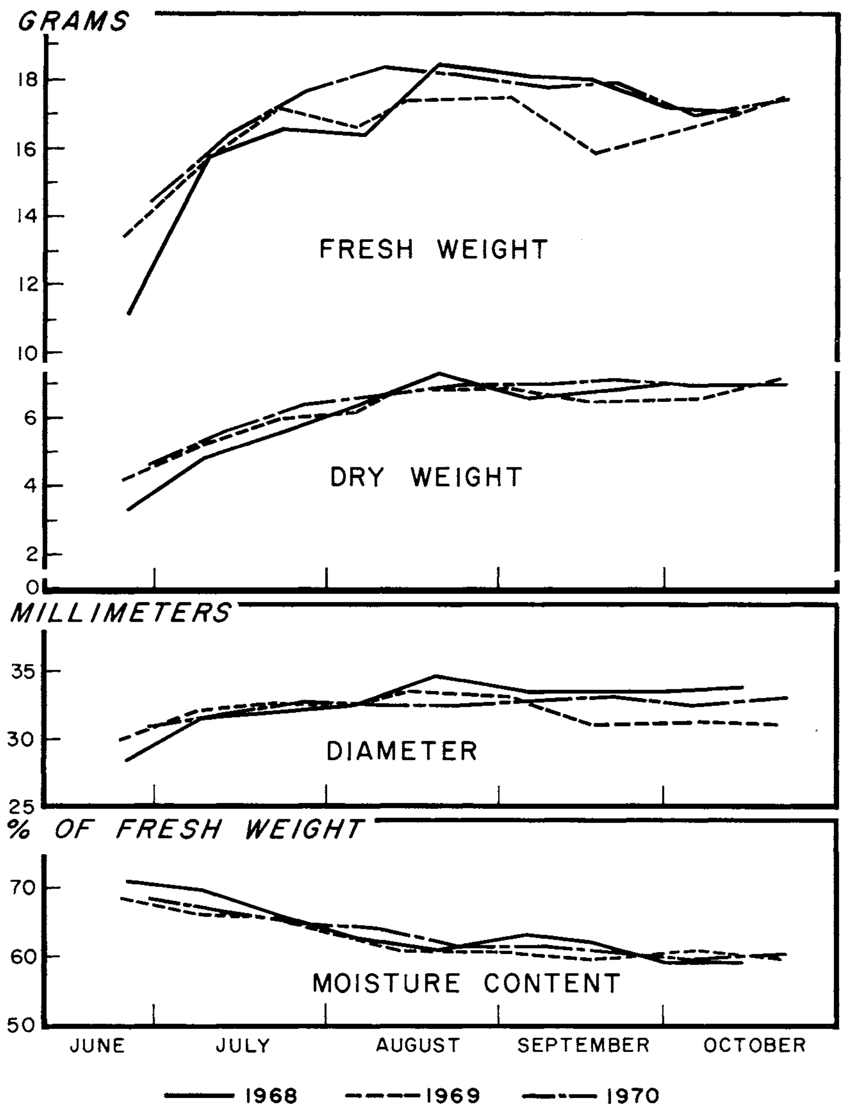

FIGURE 2. *Seasonal changes in fresh weight, dry weight, diameter, and moisture content of sycamore fruits.*

dried in the laboratory and their seeds extracted. Sweetgum seeds were stratified for 30 days at 3°C; sycamore seeds were not stratified. Germination was tested on blotter paper under diurnally alternating temperatures of 20° and 30°C; light was provided during the 30° period.

In 1969, 5 to 10 extra fruits were collected from a sample tree of each species that had fruited normally and consistently in previous years. The fruits were dried for 24 hr at 70°C, and the seeds were ground in a Wiley mill to pass a 40-mesh screen.[1] The seeds were separated from sweetgum fruits, and the two fractions were ground separately. Sycamore seeds were removed from the central head, and only the seeds and their hairy tufts were ground for analysis.

[1] In the latter part of the season, a 20-mesh screen was used for sweetgum seeds because of the high fat content.

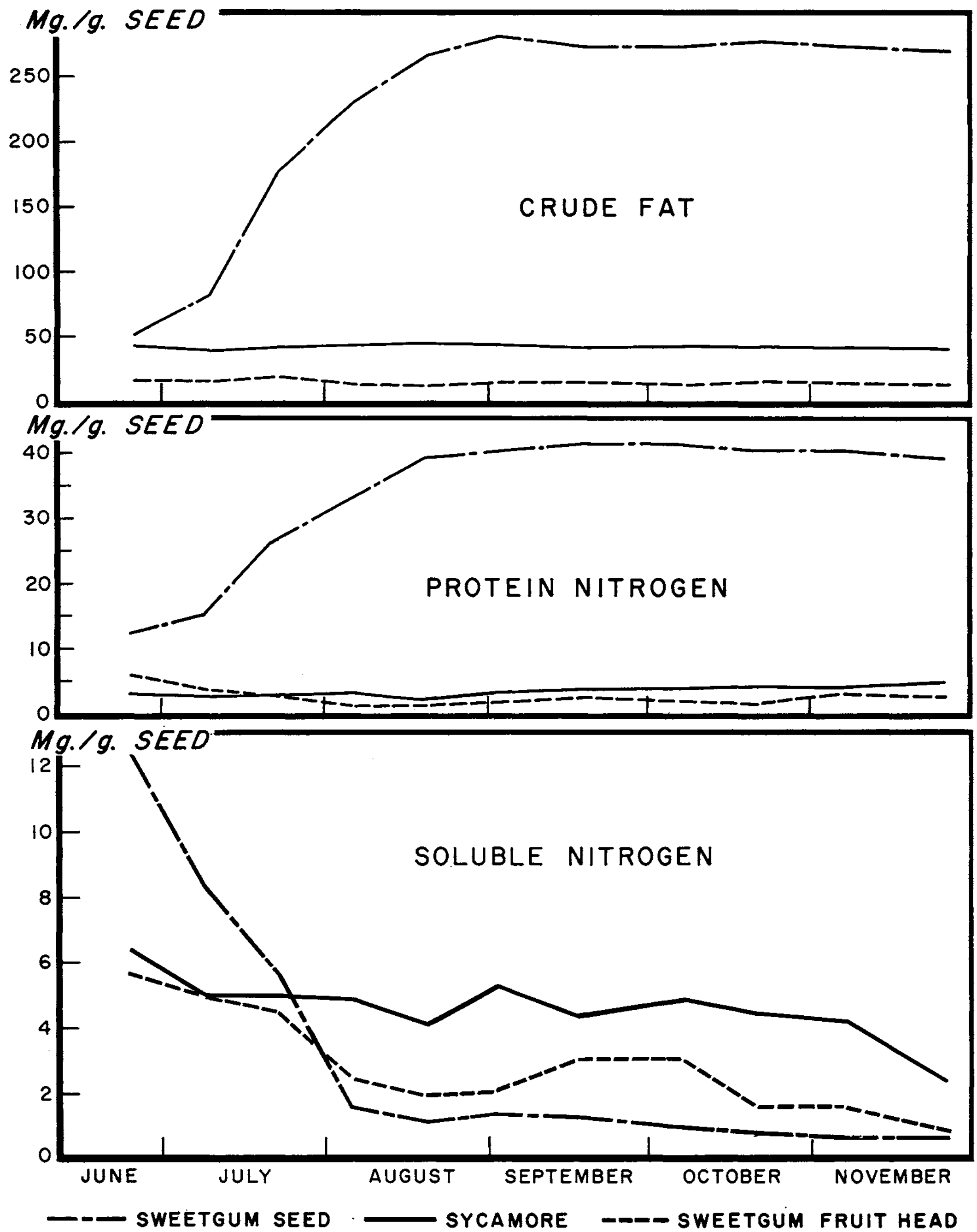

FIGURE 3. *Seasonal changes in crude-fat, protein-nitrogen, and soluble-nitrogen contents of sweetgum seeds and fruit heads and sycamore seeds.*

Crude fat was determined gravimetrically from 1.0-g samples which were extracted with petroleum ether for 7 hr in a Soxhlet apparatus.

Soluble carbohydrates and nitrogen fractions were extracted from 1.0-g samples with 80-percent ethyl alcohol in a Soxhlet apparatus. The solid residue was weighed

TABLE 1. Seed dry weight and germination of seeds collected from two sweetgum trees and two sycamore trees in 1969.

	Sweetgum				Sycamore			
	Tree 3		Tree 6		Tree 2		Tree 5	
Collection date	Seed dry weight	30-day germination[a]	Seed dry weight	30-day germination[a]	Seed dry weight	15-day germination[b]	Seed dry weight	15-day germination[b]
	Mg	*Percent*	*Mg*	*Percent*	*Mg*	*Percent*	*Mg*	*Percent*
June 24	1.0	—	—	—	1.1	—	1.4	—
July 8	1.4	—	1.7	—	2.0	—	1.7	—
July 22	2.4	—	2.8	—	2.3	—	2.2	—
August 5	3.0	—	3.6	—	2.1	—	2.2	—
August 14	4.0	97.0	4.0	91.5	2.1	20.0	3.2	0
September 2	4.0	75.0	3.9	92.9	3.1	31.0	2.8	27.0
September 17	5.0	100.0	5.3	99.1	3.1	32.0	3.0	28.0
October 6	4.6	100.0	5.4	97.1	2.9	24.0	2.8	13.0
October 21	4.7	100.0	5.0	100.0	3.7	20.0	2.9	27.0

[a] Germination percent of a single composite lot, based on full seed as determined by a cutting test of ungerminated seeds.

[b] Germination percentages are averages for two 50-seed lots.

and stored in a freezer for later analyses of protein nitrogen and insoluble carbohydrates. Soluble nitrogen in the alcohol extracts was determined by micro-Kjeldahl procedures. Aliquots which contained up to 50 micrograms of carbohydrates were analyzed for total soluble carbohydrates by the phenol-sulfuric acid method (Nalewaja and Smith 1963).

Nitrogen content of 35-mg samples of the solid residue was also determined by micro-Kjeldahl procedures. The result was taken as protein nitrogen, and amounts were expressed on the basis of original seed dry weight.

To measure starch and other insoluble carbohydrates, 0.1-g samples of the solid residue were soaked in distilled water for 24 hr and hydrolyzed with 1.2 N HCl over low heat for 2.5 hr. After filtering, pH was adjusted to 5.0 with NH_4OH, and total carbohydrate content was determined on an aliquot by the phenol-sulfuric acid method (Nalewaja and Smith 1963). Results are expressed per unit of original seed dry weight.

Phosphorus, calcium, and magnesium were determined from acid extracts of 1.0 g samples ashed at 450°C. Phosphorus was determined by the chlorostannous-reduced molybdophosphoric blue method (Chapman and Pratt 1961, Jackson 1958). Calcium and magnesium were determined with an atomic absorption spectrophotometer.

All analyses were done in duplicate and repeated for agreement within 10 percent of the mean. Great variation in sweetgum fruit head material prevented such agreement in some cases.

Results

Physical Characteristics. Sweetgum fruits reached full size by late June and changed little during maturation. Fresh and dry weights of fruits increased slightly (Fig. 1), and moisture content decreased.

Sweetgum fruit specific gravity was very stable throughout the measurement period. It averaged 1.05 to 1.15 and gave no promise as a maturity index for this species.

Individual sweetgum seeds increased three- to five-fold in dry weight during maturation. Typical data from two trees in 1969 show steady increases in seed dry weight to a peak in the last half of September, and a slight drop after that (Table 1).

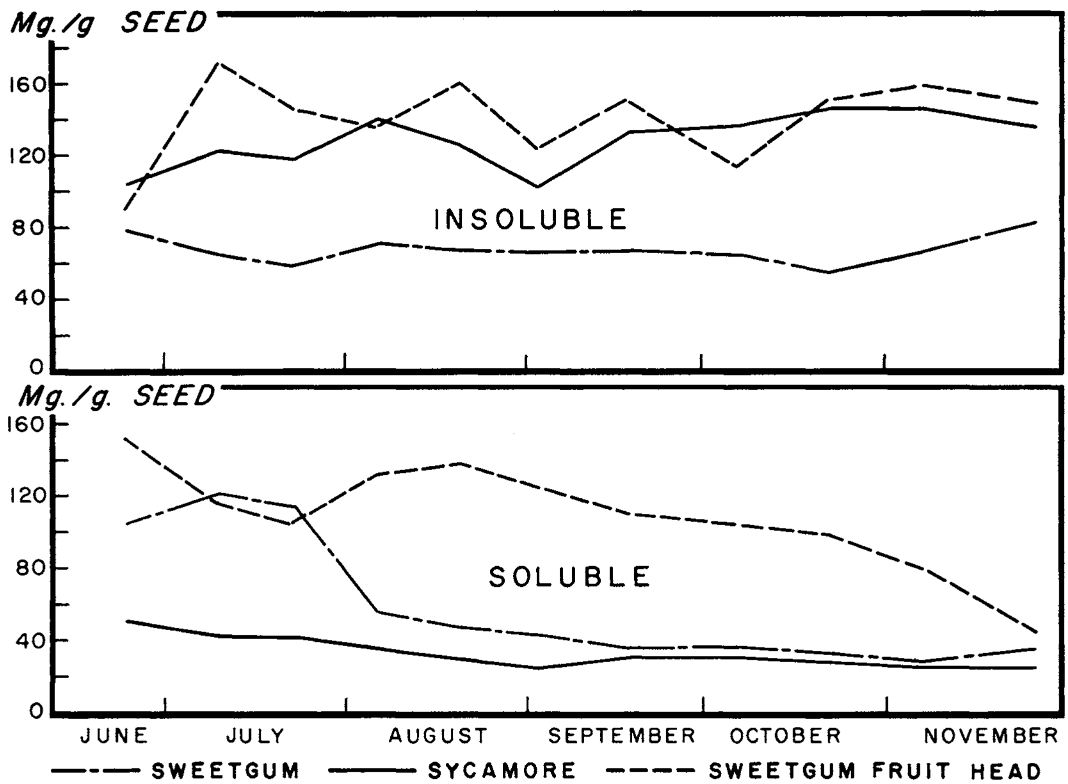

FIGURE 4. *Seasonal changes in soluble and insoluble carbohydrate contents of sweetgum seeds and fruit heads and sycamore seeds.*

Germination data from these seeds suggested that physiological maturity was reached by at least August 15. Almost identical results were obtained in 1968 on a different sample tree.

Physical changes in sycamore fruits showed a pattern similar to that of sweetgum, but the increases in fresh and dry weight were much greater (Fig. 2). Fruit diameter increased very slightly during the measurement period, and fruit moisture content decreased steadily during the season. Moisture content was about 10 percent below that of sweetgum fruits (Fig. 1).

Specific gravity of sycamore fruits varied only a little during the study period and showed no promise as a maturity index.

Individual sycamore seeds gained in dry weight during maturation just as sweetgum seeds did, but the increase was not as great (Table 1). Seed dry weight peaked in late August and early September. Germination tests show that the seeds were physiologically mature at that time.

Chemical Characteristics. Crude fat content of sweetgum seeds increased to a peak of about 275 mg per gram of seed by late August; there was little change in fruit head tissue (Fig. 3). This accumulation to 25 or 30 percent of dry weight indicates the importance of lipids as storage food in sweetgum. Sycamore, on the other hand, maintained a low and stable level of crude fats during maturation.

As expected, soluble nitrogen decreased and protein nitrogen increased during maturation of sweetgum seeds (Fig. 3). A more moderate loss of soluble nitrogen occurred in sweetgum fruit tissue, but there was no corresponding increase in protein nitrogen. During maturation, soluble nitrogen decreased and protein nitrogen increased slightly in sycamore seeds (Fig. 3). Assum-

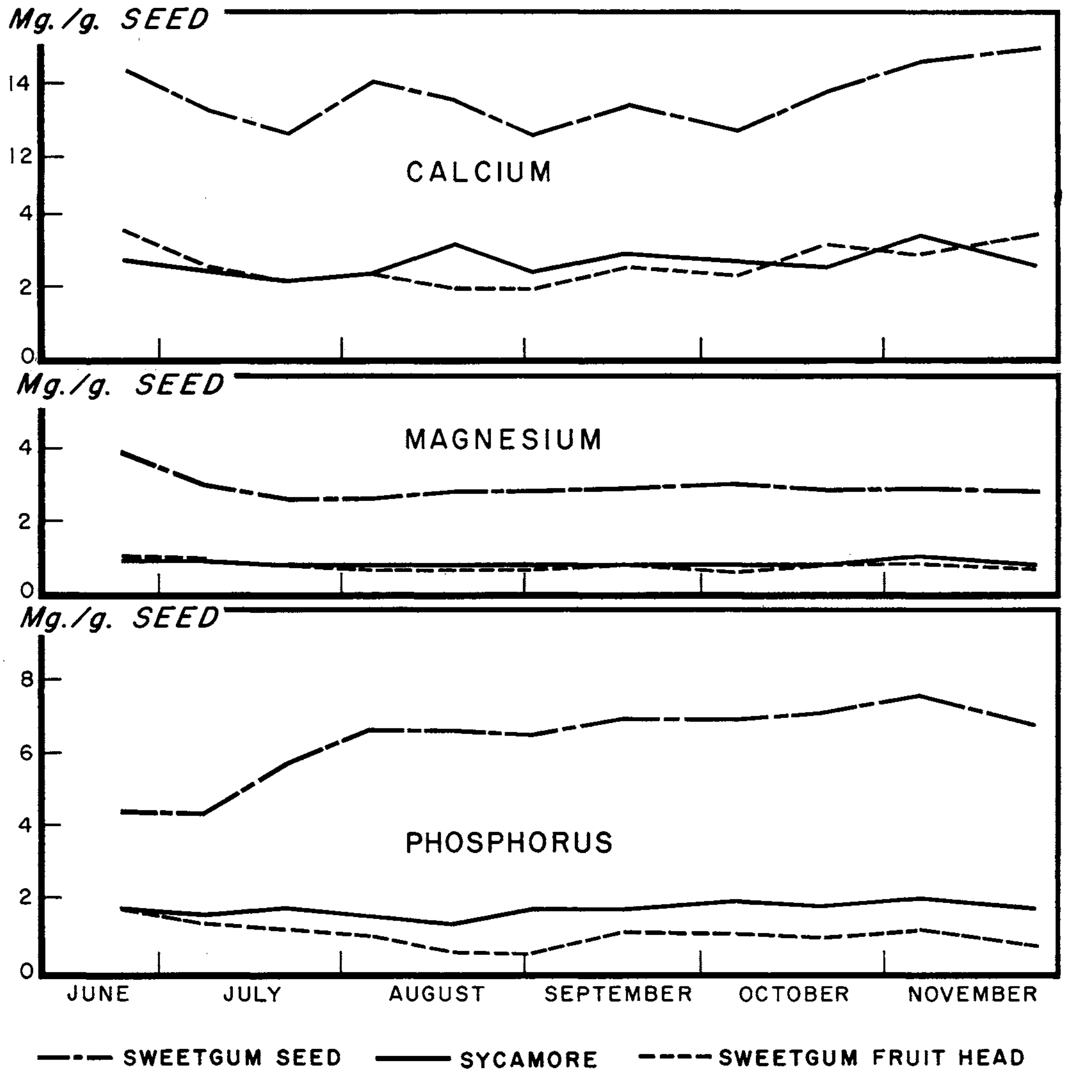

FIGURE 5. *Seasonal changes in calcium, magnesium, and phosphorus contents of sweetgum seeds and fruit heads and sycamore seeds.*

ing that protein content is 6.25 times protein nitrogen content (Jackson 1958), mature sweetgum seeds contained about 25 percent crude protein, and sycamore seeds only 3 percent.

Soluble carbohydrate contents decreased in both sweetgum and sycamore as the seeds matured (Fig. 4). Concentrations of insoluble carbohydrates rose in sycamore but not in sweetgum seeds. The carbohydrate fractions together totaled about 16 percent of seed dry weight for sycamore and 12 percent for sweetgum seeds at maturity. Apparently, carbohydrates are important food reserves in both species. Staining of the solid extract residues with IKI (Jensen 1962) indicated that no amylose was present in the insoluble fraction of either species.

Phosphorus concentration increased in sweetgum seeds during maturation and decreased slightly in fruit tissue. Phosphorus levels in sycamore were stable (Fig. 5).

Magnesium contents varied little, except for a decrease from June through July in sweetgum seeds (Fig. 5). Calcium levels were also stable in both species. Concentrations in sweetgum seeds were three to four times those in sycamore seeds.

Discussion

The data reported give a general view of maturing sweetgum and sycamore seeds. Weights, sizes, and moisture contents varied between individual trees, but the yearly mean values plotted against time of collection yielded very similar curves each year. Even data from the poor seed year of 1968 fit the patterns well.

There are no published data on chemical contents of seeds of these species, but similar increases in crude fat and protein nitrogen and decreases in soluble nitrogen and some carbohydrate components have been reported for other tree seeds during maturation (Rediske 1961, Rediske and Nicholson 1965, Schubert 1961). The small changes in chemical components of sycamore probably reflect the low numbers of viable seed present. Only 25 to 30 percent of the seeds from the sample tree were filled. Most of the remaining tissue is relatively stable and "dilutes" the chemical changes in seeds.

Sweetgum seeds steadily gained weight as they approached physiological maturity in mid-August. Since immature fruits picked as early as mid-July can be artificially ripened (Bonner 1970a), most of the food reserves that accumulated in seeds probably were in the fruit tissue by late July or early August.

Seeds of both species were capable of normal germination before any visible changes in the fruits were evident. Specific gravity of fruits did not indicate this maturity, although Wilcox (1966) reported great changes in specific gravity of sweetgum fruits in southern Mississippi. A crude fat content of about 25 percent is apparently a good chemical index for sweetgum maturity, but there were no good chemical indices established for sycamore with these data. Fruit color changes from bright green to pale green or yellow-green in sweetgum and from green to yellow or brown in sycamore after the seeds are mature and well before dissemination from the tree (Bonner 1970b). These color changes are still the best maturity indices for general collections.

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