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Carbohydrates in Two *Rhododendron* Cultivars[1]

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Abstract. Determinations of carbohydrates in the plant organs of *Rhododendron* spp. cv. 'Sweetheart Supreme' and 'Hexe', were made by chemical analysis, thin-layer chromatography (TLC) and gas-liquid chromatography (GLC). Reducing sugar content was 1.5 times higher in buds than in leaves for 'Hexe' with no significant differences for 'Sweetheart Supreme'. Reducing sugars were also higher in the roots than stems with both cultivars. Sucrose content was 1.4 times greater in leaves than in buds of 'Hexe' and 1.6 times greater in 'Sweetheart Supreme'. Starch was significantly higher in leaves and buds than in stems and roots. The predominant soluble sugars identified by TLC and GLC were sucrose, glucose, and fructose. Small but detectable amounts of raffinose and maltose and an unidentified compound were also found in the plant organs.

Studies of the identification and distribution of carbohydrates in woody plant material have dealt primarily with forest trees. Wargo (10) reported the presence of starch, sucrose, glucose, fructose, stachyose, raffinose and maltose in the roots of sugar maple. In white pine stems, Parkerson and Whitmore (8) showed the occurrence of starch, sucrose, glucose and fructose but no stachyose or raffinose. However, Zimmerman (11) found traces of sucrose, raffinose and stachyose in the sieve-tube exudates of forest trees. Similar information on woody ornamental shrubs is limited, although Jeremias (3) reported the presence of sucrose, raffinose, glucose, stachyose and sedoheptulose in the bark of *Picea abies* and wood of *Euonymus europaeus*. The purpose of this study was to determine the amount and identity of the major sugars and starch in the different organs of 2 *Rhododendron* cultivars.

Materials and Methods

Leaves, buds, roots and stems of 2 fully budded field grown *Rhododendron* cultivars were purchased from a nursery on Feb. 15, 1975, and used for carbohydrate determinations. Tissues from 4 replicates with 3 plants per replicate of each cultivar were lyophilized for 36 hrs and ground in a Wiley mill to pass a 40-mesh sieve. A 200 mg composite sample from 3 plants of each replicate and for each of the organs was extracted with 80% ethanol for 4 hours in a micro-Soxhlet apparatus. The alcoholic extracts were evaporated to a cloudy aqueous phase *in vacuo* at 40°C, diluted to 15 ml with distilled water and centrifuged. The supernatants were then used for quantitative and qualitative analysis of the soluble carbohydrates in the plant organs. Starch extractions were made on the residue remaining after ethanol extraction according to Aung et al. (1).

Quantitative determination of sugars in the ethanolic extracts was made by Nelson's method (7) with glucose as a standard. Sucrose was hydrolyzed to reducing sugars by adding an equal volume of 0.05 M sodium acetate buffer, pH 4.7, containing 0.2 mg/ml of yeast invertase to each sample and incubating for 30 min at 25°C. The amount of sucrose was calculated from the difference between total reducing sugar after invertase treatment and reducing sugar before enzyme hydrolysis.

Qualitative examination of the sugars in the ethanolic extracts from the roots of 'Hexe' was made by thin-layer chromatography (TLC) and gas-liquid chromatography (GLC). For TLC, 20 x 20 cm glass plates were coated with a 250 μ layer of either Kieselguhr G or silica gel G. The plates were developed to 15 cm at 26°C using solvent A consisting of n-butanol, acetone and 0.1 M phosphate buffer at pH 5.0 (4:5:1 v/v), and solvent B consisting of 60 ml ethylacetate, and 35 ml mixture of isopropanol and water (2:1 v/v). For detection of the known and unknown sugar spots, the developed Kieselguhr G plates were sprayed with a reagent mixture of 9 ml 95% ethanol, 0.5 ml concentrated sulfuric acid and 0.5 ml of anisaldehyde and the silica gel G plates a reagent mixture of equal volumes of 20% sulfuric acid and an alcoholic 0.2% naphthoresorcinol. Plates were dried at 105°C for 5-10 min. Sugars for analysis by GLC were obtained from an alcoholic extract from 25 mg of dry root tissue. This extract was chromatographed on Kieselguhr G plates developed with solvent A. Areas corresponding in R_f to authentic raffinose and maltose were

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removed from the plates and eluted with 80% ethanol for further analysis by GLC. For this purpose, a Bendix 2500 gas chromatograph equipped with a flame ionization detector and U-shaped glass column 1.82 m x 4 mm i.d. packed with a 3% OV-17 on 80/100 mesh Gas Chrom Q (Supelco, Inc., Bellefonte, PA) was used. GLC was performed under the following conditions: 5 min isothermal operation at 220°C and then linearly programmed at 4°/min to 250°C; detector at 250°C, inlet at 240°C and He_2 flow rate at 40 ml min^{-1}. The trimethylsilyl derivatives of authentic sugars and the n-dried TLC eluates of the unknown samples were prepared by direct trimethylsilylation using N,O-Bis-(trimethylsilyl)-acetamide (Pierce Chemical Co., Rockford, IL). A 1-3 μl sample of this solution was injected for GLC analysis after 30 min at 60°C.

Quantitative estimates of maltose and raffinose present in the root extracts after TLC were made by comparing the peak areas obtained by triangulation (½ base × height of peak) of the unknown peaks with peak areas of authentic maltose and raffinose of known concentrations. The procedure is 98% accurate and is based upon the assumption that the peak areas obtained are proportional to the particular chemical peak's concentration (5).

Results

The reducing sugar content in the buds of 'Hexe' was 1.5 times higher than in the leaves but no significant difference was seen between the buds and leaves of 'Sweetheart Supreme' (Table 1). Also, reducing sugars were significantly higher in the roots than stems of both cultivars. The amount of reducing sugars in the buds, stems and roots of 'Hexe' was the same as in those of 'Sweetheart Supreme', but the amount in the 'Hexe' leaves was 1.6 times lower. On the other hand, sucrose content in the 'Hexe' leaves was 1.4 times greater than that of the buds and 1.6 times greater in the leaves than the buds of 'Sweetheart Supreme'. The amount of sucrose in the leaves, buds and roots of 'Hexe' was significantly greater than those of 'Sweetheart Supreme', but there was no difference in the stems. On a plant basis, there was 1.8 times more sucrose in 'Hexe' than 'Sweetheart Supreme'. Starch was significantly higher in buds and leaves than the stems and roots but did not vary between cultivars.

TLC examination of the leaves, buds, stems and root extracts of 2 *Rhododendron* cultivars indicated the predominant sugars to be fructose, glucose, sucrose and lesser amounts of raffinose and maltose. But since the sugars of the extracts did not differ in kinds by only in amounts, and raffinose and maltose were more prevalent in the roots than leaves, stems and buds, only the root extract was studied further and data presented (Table 2). Data obtained by silica gel G were not presented since resolution of the unknown sugars in the organ extracts with the 2 solvent systems was unsatisfactory.

Table 1. Alcohol-soluble sugars and starch in organs of 2 *Rhododendron* cultivars.

Organs	mg/g dry wt of tissue[z]					
	Reducing sugars		Sucrose		Starch	
	'Sweetheart Supreme'	'Hexe'	'Sweetheart Supreme'	'Hexe'	'Sweetheart Supreme'	'Hexe'
Leaves	88**	54	21**	43	20	18
Buds	83	80	13**	31	19	18
Stems	34	33	14	18	7	8
Roots	47	52	10*	17	8	7
Values for significance between organs						
5%	11		10		4	
1%	8		7		3	

[z] Means are values of 4 replicates of 3 plants/replicate.
** Indicates significant difference between cultivars at 1% level of probability.
* Indicates significant difference between cultivars at 5% level of probability.

Table 2. Thin-layer chromatography of *Rhododendron*, cv. Hexe, root extract on Kieselguhr G in solvent systems[z]

Compound	$R_f \times 100$	
	Solvent A	Solvent B
Authentic		
Raffinose	3	18
Maltose	11	19
Sucrose	18	23
Glucose	24	34
Fructose	38	44
Root extract		
	3	17
	9	—
	11	18
	18	23
	26	35
	35	45

[z] Solvent A; n-butanol:acetone:phosphate buffer, pH 5.0 (4:5:1 v/v). Solvent B; 60 ml ethylacetate:35 ml mixture of isopropanol and water (2:1 v/v).

Table 3. Gas-liquid chromatography of sugar standards and *Rhododendron*, cv. Hexe, root extract after TLC[z]

Authentic standards	Unknown TLC spots[y]	
	Maltose	Raffinose
Sucrose (9.3)	9.4	—
Maltose α(10.0)	—	—
β(10.6)	10.7	—
Raffinose (31.2)	12.2	31.2

[z] Values are retention time (min) from the point of injection. See details in Materials and Methods for GLC operating conditions.
[y] Areas of unknown compound from root extract which co-chromatographed with authentic maltose and raffinose were eluted from TLC plates.

The presence of raffinose and maltose in *Rhododendron* was verified by GLC (Table 3). Calculation indicated that raffinose and maltose were present at 400 and 170 (0.04% and 0.017%) μg/g dry wt of roots respectively. An unidentified compound with a retention time of 12.2 min along with small amount of sucrose was also detected in the maltose sample taken from TLC.

Discussion

The carbohydrates of 'Hexe' and 'Sweetheart Supreme' plant organs did not differ qualitatively and consisted mainly of glucose, fructose, sucrose, starch and a lesser amount of maltose, raffinose and an unidentified sugar. There were quantitative differences, however, in the carbohydrate contents of plant organs within each cultivar and between the 2 cultivars. The amount of total carbohydrates in the leaves and buds constituted 67% on a dry wt basis. This observation contrasts sharply with deciduous species which store a larger amount of their carbohydrates in the stems and roots (6). On the other hand, the higher amount of carbohydrates in *Rhododendron* roots than the stems was consistent with the results reported for a number of plant species (2, 4, 6).

Raffinose is present in *Rhododendron* tissues with higher amount in roots. It also occurs in the bark and wood of *Euonymus europaeus* and *Picea abies* (3), and the sieve-tubes exudates of 16 tree species (11). Its role in *Rhododendron* and other species is unclear. Zimmerman (11) suggested that raffinose may be a transport sugar in trees. Considering the molecular size of raffinose, its preponderant occurrence in the roots and mobilization during development (9), it is more likely that raffinose is a storage sugar. This suggestion would also be

in accord with the observation that raffinose occurs in relative greater abundance when growth is slow and disappears with growth resumption (9).

Maltose was also found in leaves, stems, buds and roots of *Rhododendron* but was more abundant in roots. Similar observations have been made in sugar maple roots where maltose occurs from late summer to late spring (10). The metabolic role of maltose in *Rhododendron* is unknown but it is probably a breakdown product of starch.

Based upon its slow migration rate in TLC and long GLC retention time, and unidentified sugar in *Rhododendron* appears to be a relatively large molecule resembling either a trisaccharide or a tetrasaccharide. Like raffinose, it is probably also a storage sugar.

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An Economic Evaluation of Consumer Characteristics Affecting Sweet Potato Consumption[1]

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Abstract. The purpose of this report was to relate several economic and social characteristics of sweet potato consumers to level of fresh sweet potato consumption. National cross-sectional data were used to identify consumption patterns using the least squares regression procedure. Relationships were estimated for white and non-white households.

The relationships for white households indicated that price of sweet potatoes, family income, number of meals eaten- at-home, family size, and expenditures for white potatoes were important determinants of weekly sweet potato consumption. Regional, urbanization, and seasonal differences were also apparent for white households. Education, age, and employment status were not critical in determining consumption patterns.

The relationship for the non-white households was similar structurally to the white household relationship but the sample size was not sufficiently large to yield statistically significant coefficients for some of the variables found important in the white household. Nevertheless, price, age and number of households did exhibit statistically significant coefficient. Seasonal and urbanization differences were noted.

Sweet potato merchants should find the relationships useful in market segmentation. Sales efforts should take into account at least regional, seasonal, and urbanization differences.

Per capita consumption of sweet potatoes has been declining for several years. Annual consumption of fresh sweet potatoes has declined from around 15 pounds in the mid-1940's to about 3 pounds per capita today (3). This change in consumption level has resulted from a decline in number of households purchasing sweet potatoes, and the amount of potatoes each household purchases per week. For example, a national survey of 6,060 households in the spring of 1955 indicated that 7.1 percent of households purchased sweet potatoes. The average weekly purchase in the spring of 1955 amounted to .16 pounds per household for all households. Weekly per capita consumption was .67 pounds for those household actually purchasing sweet potatoes (2). The situation changed considerably during the next 10 years. The 1965 spring survey of 7,532 households detected only 4.7 percent of all households purchasing sweet potatoes. Weekly household consumption dropped to .09 pounds for all households. Weekly per capita consumption was .58 pound for those households actually purchasing sweet potatoes (4).

Population in the United States has increased at a rate which has tended to offset the effects of downward per capita consumption leaving total consumption of sweet potatoes almost unchanged over the period. Prices have increased during the period but not rapidly enough to yield increasing real prices after taking account of inflation (1).

Several economic and social characteristics of consumers are no doubt important in explaining the downward trend of per capita consumption of sweet potatoes. The 1965 National Consumer Survey of Household Consumption is the most recent source of data which can be used to measure the importance of these characteristics on consumption. The purpose of this report is to present the results of an analysis of these data to identify factors that are important in determining 1) whether consumers buy sweet potatoes and 2) what amount is consumed if the decision is to purchase.

Materials and Methods

Consumption relationships were estimated by ordinary least squares regression using cross-sectional data. These data, obtained

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