Rebaudi's stevia: natural noncaloric sweeteners

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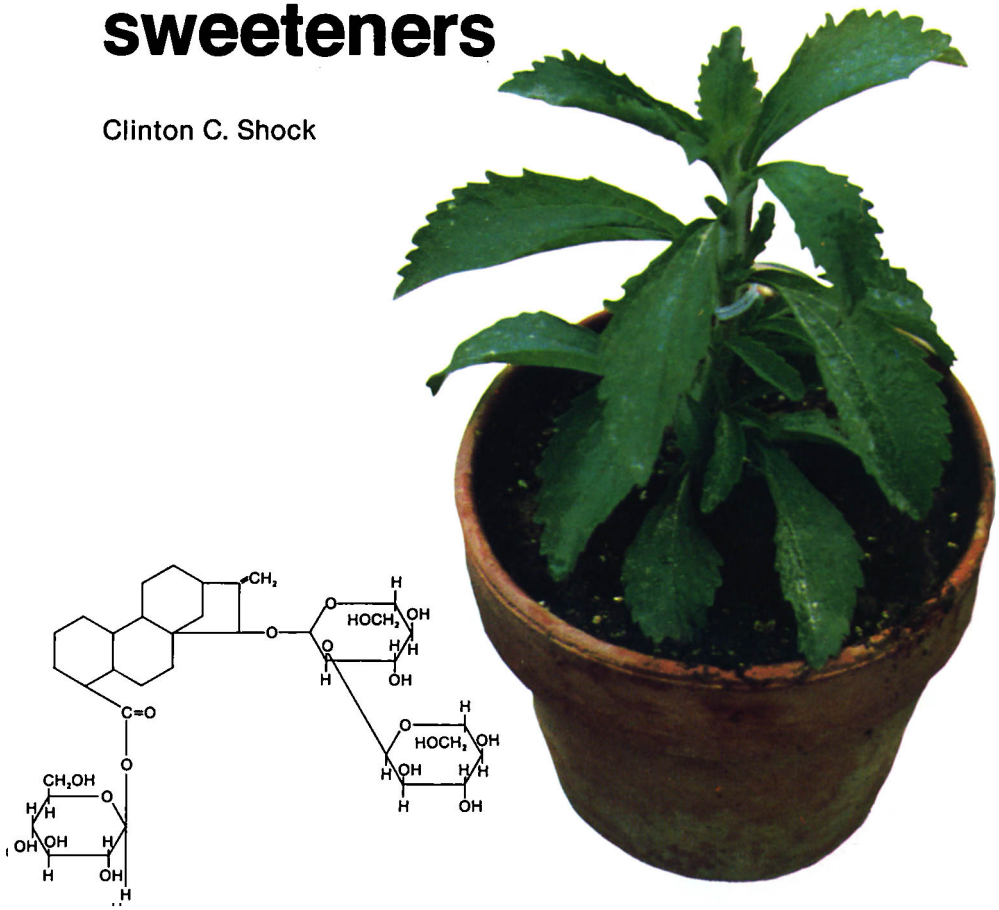

Stevia contains chemical compounds 250 times as sweet as sugar. Of special interest are compounds that have glucoside groups attached to a three-carbon-ring central structure.

Leaves of Rebaudi's stevia, a plant used historically in Paraguay as a sweetener and herbal remedy, contain compounds about 250 times as sweet as table sugar. Preliminary trials at the University of California, Davis, have shown that production of one of the compounds, stevioside, could be equivalent to the sweetening power of 28 tons per acre of sucrose. However, much needs to be learned about production problems before the plant can be grown commercially.

The plant, *Stevia rebaudiana* Bertoni, belongs to the eupatory tribe of the composite family and is native to northeastern Paraguay. It is related to other members of the genus found in the United States and in Central and South America.

The chemicals of interest are stevioside, rebaudioside A, and at least six other sweet compounds that have glucoside groups attached to a three-carbon-ring central structure. Stevioside concentrations usually range between 3 and 10 percent of the leaf dry weight; rebaudioside A is less concentrated, ranging from 1 to 3 percent.

Stevioside has also been of interest as a source of gibberellins, plant growth hormones, most of which are not available commercially. The glucoside groups are removed from stevioside to yield steviol. Modified or normal steviol has been placed in the growth medium of *Gibberella fujikuroi* mutants to produce several gibberellic acids. Gibberellic acid, GA_{20}, is known to occur naturally in stevia leaves but not in commercial quantities.

Possible health risks from human consumption of the various compounds in *Stevia rebaudiana* are not well defined and are being studied by others.

Climate and growth

In northeastern Paraguay, stevia populations have been found in the watershed of the Ypane River at an elevation of about 650 feet. Grazing, harvesting, and transplanting of stevia to cultivated areas has reduced its natural occurrence. Plants occur naturally on the edges of marshes or in grassland communities on soils with shallow water tables. All sites are continuously moist but not subject to prolonged inundation. The soils are typically infertile acid sands or muck. The climate can be characterized as semihumid subtropical with temperature extremes from 21° to 110°F. Average annual temperature is 75° F, and rainfall about 55 inches per year.

In competition with natural vegetation, stevia is a slender perennial herb growing to 24 inches tall. The plant remains vegetative in the spring through early summer and flowers in the late summer and fall as a short-day plant. Shoots usually die after maturing or are frosted off; new growth comes from tillering at the plant base. In the wild it reproduces by seed, crown division, or rooting of branches that lodge or are trampled by cattle. Production of viable seed is erratic. Most of the plants alive in the wild are survivors from plants present the previous year.

Cultivation

When stevia is cultivated in or near its natural habitat, it is much more vigorous than in natural populations, reaching 3 feet or more in height. Branching and tillering are also much more profuse. The plant requires frequent irrigation and competes poorly with weeds. Currently stevia is under experimental cultivation in Brazil, Japan, Korea, Taiwan, and Southeast Asia, as well as in Paraguay.

Little is known about cultural practices that would allow efficient commercial cultivation of this crop in California. The partial information available from other areas is useful. Also some of the physiological requirements and agronomic potential can be deduced from the plant's origin.

Occurrence of stevia on acid, infertile sandy or muck soils with ample supplies of water is consistent with observations of plant performance under cultivation. Frequent shallow irrigations apparently are needed, and the plant has poor tolerance of water stress. The plant has little salt tolerance, so it should not be grown in saline soils or with poor quality water. Most agricultural soils are more fertile than soils where the plant originated, so fertilization requirements are expected to be minimal. In Korean experiments, leaf yield increases resulted from moderate applications of nitrogen, phosphorus, and potassium fertilizers.

Poor germination in cold weather, slow initial seedling growth, and greater yields by early planting have led producers in Korea and other temperate regions to start plants indoors and then transplant outside in early spring. Seeds germinate better when given light and warm temperatures, but plants are more productive when seedlings or rooted cuttings are set out as early as possible in the

spring. Plants will overwinter in Davis, California, and may be grown as a perennial.

Short days promote flowering. In its native habitat at 21° to 22° S latitude, plants start flowering from January to March, equivalent to July to September in the northern hemisphere. Subsequent flowerings occur in rapid succession as regrowth from the plant crown grows shorter each time until winter in July.

Long days favor leaf yields and leaf stevioside contents. Consequently, plant growth in temperate areas with long summer days would be ideal for high stevioside yields, but seed production would be difficult.

In its region of adaptation, stevia competes with other small plants adapted to infertile soil. Under cultivation, weeds grow much faster than well-established stevia plants, and weed control remains a problem.

Experimental cultivation

Seeds and live plants were collected by the author in the wild along tributaries of the Ypane River in Paraguay. Seeds were planted in the greenhouse and in the field at the University of California, Davis, to monitor survival. Germination occurred mostly on the sixth day and was very poor. About 200 stevia plants were set out in the field in 1979 to find those that would overwinter. Eighteen lines survived the moderate winters of 1979-80 and 1980-81. Plant tops died back completely after light frosts except for line 18, which retained green branches.

Sprouting began in March, but significant growth did not occur until April. Slugs threatened survival of resprouting plants in the spring. Flowering occurred in October, but frost or cold weather terminated the reproductive cycle in November before seed development was completed.

The 18 lines were clonally propagated to compare productivity of the surviving lines and to collect information on harvesting the plants for leaf production. Cuttings were taken from different parts of the plant to determine the best parts for vegetative propagation. Cuttings were made from the growing tips of branches, the second 3-inch segment down the branch, or other parts of the plant top. These cuttings were kept separate by clone and plant part, and success of rooting and vigor of rooted cuttings were measured.

All plant parts from all clones rooted successfully under mist. Cuttings from the growing tips of branches rooted most quickly and grew into the largest plants. Plant dry weights after 100 days reflect the difference in initial vigor (dry matter averaging 2.9 grams for the growing-tip cultures as opposed to 0.9 for plants derived from other cuttings), even though these differences were minimized by competition by other cuttings in the dense stand.

In a greenhouse experiment to test relative productivity of 17 of the surviving clones of stevia, several clones were more productive than the others. Stevioside content of each clone has not been determined.

A field clipping trial was planted in 1981 with plants of one clone, line 1, to obtain data on stevia productivity as a function of plant density and harvesting strategy. Plants were established at different densities and fertilized with nitrogen.

When plants were clipped just once, at the end of the growing season, dry matter yield averaged 920 grams per square meter. Plants yielded a total of 200 grams per square meter when clipped three times during the season to a height of 2 inches. The plants clipped at 2 inches had a very low survival rate after the first clipping, and dry matter yields dropped off precipitously.

Stevia grown at Davis gave the greatest yields when harvested only once at the end of the growing season. Yields of 900 grams dry matter per square meter appear to be possible. If this yield consists of 40 percent leaf, and if the leaf contains 7 percent stevioside, there would be 25 grams of stevioside per square meter, the sweetening equivalent of 6.3 kilograms per square meter of sucrose. This would translate into 220 pounds of stevioside per acre with a sweetening power equivalent of approximately 28 tons per acre of sucrose sugar.

Possible planting sites

Stevia apparently will produce best where there is a long growing season, minimal frost, high light intensities, and warm temperatures. The plant is not adapted to water stress or saline conditions. Stevia occurs naturally on acid soils of pH 4 to 5 but will grow well on less acid to neutral soils with a pH of 6.5 to 7.5.

Although a wide range of sites for experimental plantings might be tried throughout the state, southern coastal valleys away from the immediate influence of coastal fog would appear to be the most suitable. Any production should be attempted with caution appropriate for a new crop with untested potential and problems.

Research needs

Stevia is still a plant of very recent domestication. It is believed that yield improvements can be achieved by selection and breeding for stevioside content, leaf-to-stem ratios, and plant response to fertilization. Other aspects needing investigation include methods of propagation, weed control, and water management. Plants with high production of viable seed need to be found. Optimal fertilizer formulations for California need to be determined. Research in these areas might result in a new crop plant for California agriculture.

No seed is available for distribution at this time. A limited number of rooted cuttings are available. For further details and a list of references, the article "Experimental Cultivation of Rebaudi's Stevia in California," Agronomy Progress Report 122, is available from Department of Agronomy and Range Science Extension, 135 Hunt Hall, University of California, Davis, CA 95616.

In its natural surroundings in Paraguay, stevia grows to 24 inches tall. In trials at Davis, the plant produced sweetening power equivalent to 28 tons per acre of sucrose sugar.

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