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The Sugar Beet Crop

Science into practice

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Introduction

D.A. Cooke and R.K. Scott

Sugar beet is one of just two crops (the other being sugar cane) which constitute the only important sources of sucrose – a product with sweetening and preserving properties that make it a major component of, or additive to, a vast range of foods, beverages and pharmaceuticals.

Sugar, as sucrose is almost invariably called, has been a valued component of the human diet for thousands of years. For the great majority of that time the only source of pure sucrose was the sugar-cane plant, varieties of which are all species or hybrids within the genus *Saccharum*. The sugar-cane crop was, and is, restricted to tropical and subtropical regions, and until the eighteenth century the sugar produced from it was available in Europe only to the privileged few. However, the expansion of cane production, particularly in the Caribbean area, in the late seventeenth and the eighteenth centuries, and the new sugar-beet crop in Europe in the nineteenth century, meant that sugar became available to an increasing proportion of the world's population.

Despite concerns about effects on human health, and increasing competition from other sugars (e.g. isoglucose from cereals or high fructose corn syrup from maize) and from artificial sweeteners (e.g. saccharin, aspartame and cyclamate) the public's demand for sucrose continues. World production has increased steadily, rising from 50 million tonnes in 1959–60 to 73 million tonnes in 1969–70, 84 million tonnes in 1979–80 and 109 million tonnes in 1989–90. During the last decade about 37% of that production has been from sugar beet, with the remaining 63% from sugar cane.

Since its origins in central Europe in the early part of the nineteenth century, the sugar-beet crop has spread around the world, and it is now grown in all of the populated continents except Australia. However, it is essentially a crop of temperate regions, the great majority being grown between 30° and 60°N (e.g. from Cairo to Helsinki) in Europe (Fig. 1), Asia, North America (Fig. 2) and North Africa, with a relatively small amount (producing less than 2% of the world's beet sugar) grown in South America (in Chile and Uruguay).

The initial success of the beet sugar industry in many countries was based



Figure 1 The sugar-beet crop in western Europe. The shaded areas represent the principal beet-growing areas in Austria, Belgium, Denmark, Eire, Finland, France, the western part of Germany, Greece, Italy, The Netherlands, Poland, Spain, Sweden, Switzerland and the United Kingdom. Little is grown in Portugal and none in Norway. The crop is grown in Albania, Bulgaria, Czech and Slovak Republics, the eastern part of Germany, Hungary, Romania, Turkey, the former USSR, and Yugoslavia, but no information on its distribution was available when this map was produced.

on, or sustained by, political events (e.g. the slave revolts on the sugar-cane plantations of Santo Domingo in the 1790s, the continental blockade by British ships during the Napoleonic Wars and the depression of the 1920s when new crops were sought for derelict agricultural land in the UK). However, the ever-increasing demand for sugar, and the ability of the sugar-beet crop to satisfy that demand effectively and profitably, ensured that national sugar industries, once established, were jealously guarded. As a result, the majority of the world's sugar is now produced and



Figure 2 The sugar-beet crop in the USA. The shaded areas represent the principal beet-growing areas.

sold within the protection of preferential international agriculture and trade agreements. This leaves a small proportion to be sold on the world market, where prices fluctuate greatly but, except in rare periods of shortage (e.g. 1974–5 and 1980–1), are well below guaranteed prices.

The EC, which produces 35–40% of the world’s beet sugar, operates a sugar regime that sets national tonnage quotas for home-grown white sugar whilst permitting a limited amount of preferential imports (mainly into the UK as raw sugars from cane grown in African, Caribbean and Pacific countries of the Commonwealth). The sugar regime was intended to link community-wide production with consumption, but in fact usually results in a surplus of white sugar to be sold on the world market.

Political changes in eastern Europe, which currently also produces 35–40% of the world’s beet sugar, are almost certain to affect the distribution of sugar-producing crops in the future. For example, the political upheavals that have resulted in the fragmentation of the USSR have already stimulated a reappraisal of the special agreement that it had with Cuba, providing a guaranteed market for its enormous cane sugar industry which produces about eight million tonnes of sugar per year.

In the USA, the beet sugar industry has had to survive for almost 20 years without the degree of protection that it enjoys in other areas. The Sugar Act, which for 40 years had ensured stable prices for both growers and consumers, was not renewed in 1974, and since then prices have been subject to fluctuations in line with those which occur on the world market. In the last decade, the US crop has accounted for only around 7–8% of total world beet sugar production (compared with around 10% between

1973 and 1977) and an increasing proportion of the US caloric sweetener market has been captured by corn syrups. Many US farmers have switched to alternative crops of higher value, and the only places where there has been any expansion in beet growing are the low-input areas such as the Red River Valley of North Dakota and Minnesota.

The extent and distribution of the world's sugar-beet crop is, therefore, to a large extent determined politically, and over the next few years, attempts to liberalise trade in world agricultural products (e.g. through the GATT negotiations) may have far-reaching effects on national sugar industries. However, the very existence of those industries has depended upon the ability of agricultural scientists of many disciplines to breed varieties, and develop systems of cultivating, harvesting and processing the crop, which enable it to be grown economically in a range of climatic and social conditions. For example, monogerm varieties enabled seeds to be sown at wide spacings, ending the requirement for the labour-intensive work of thinning and singling. The new selective herbicides of the 1980s eliminated the need for hand weeding in many crops. With the introduction of mechanical harvesters, first in the USA and then in Europe, the crop no longer had to be harvested by hand. These developments meant that, in the UK for example, average labour requirements declined from about 300 man hours/ha in 1954, to 50 man hours/ha in the late 1970s, and as little as 25 man hours/ha in some crops by the late 1980s. This reduction in hand labour was greater than that associated with any other agricultural crop over the same period; without it the sugar-beet crop would not have survived the changing agricultural conditions of western Europe and the USA during the last 30 years.

Equally important in many areas were the plant protection measures that ensured the establishment and healthy growth of the crop. Pesticides, applied as seed treatments, fumigants, granules or sprays, have had, and will continue to have, a major role, but other methods, particularly the development of pest- and disease-resistant varieties, are likely to become increasingly important. Curly top resistance saved the sugar-beet crop in the western USA in the 1930s, and the rapid progress which has been made in producing rhizomania-resistant varieties may well have prevented the crop from having to be abandoned in many parts of the world in the 1990s.

Throughout western Europe and North America, most sugar-beet root crops are now produced from monogerm seeds (often pelleted and with a germination of over 95%), sown at wide spacings (usually in the spring but, in warmer climates, in the autumn to overwinter) into well-prepared seedbeds, protected from a range of weeds, pests and diseases, and adequately supplied with supplementary nutrients and, often, water. The beet roots are harvested mechanically and processed in large factories, many of which can slice over 10 000 tonnes in a day.

In other parts of the world the industry is far less technologically advanced. This is particularly apparent in the countries of eastern Europe

where years of stagnation have been a barrier to agricultural progress. There, seed quality is poor; a result of inappropriate seed crop locations, inefficient production and processing methods, and breeding programmes which have not progressed as rapidly as those in the west. Consequently, the raw seed (now usually monogerm but occasionally still multigerm varieties) which is delivered to the eastern European grower is genetically inferior to that available to his western counterpart, with a lower laboratory germination figure (<90%), and an inferior package of seed treatments. Seedbed production techniques (often involving two or three ploughings and a number of subsequent cultivations with ineffective implements) often produce over-compacted seedbeds, into which crops are sown using old-fashioned, poorly maintained drills. It is not surprising therefore that, although large numbers of seeds are sown (often around 300 000/ha), final plant populations are usually inadequate (< 50 000 plants/ha) and unevenly distributed. Herbicides, pesticides and fertilisers are often either not affordable or not available. Finally, a large proportion of the crop is lost during harvest, an operation which involves considerable manpower, even where mechanical harvesters are used. The result is that the crop is labour intensive, typically requiring 400 man hours/ha, but yields poorly; the average root yield of eastern European countries in 1985–90 was 25 t/ha at 12% sugar, whereas over the same period that of EC countries was 50 t/ha at 16% sugar.

The changes that are currently taking place throughout Europe will affect not only the politics of beet sugar production but, associated with this, the methods of beet growing in individual countries. If east European beet sugar industries are to approach the standard of performance of those in the West, the next few years will see enormous changes. Some can be implemented with relatively modest increases in investment and expertise – for example reducing the burden of perennial weed seeds, improving soil structure and correcting soil acidity problems. However, the social impact of the decreased manpower requirements of ‘modern’ crops will have far-reaching implications, and the necessary changes will not be accomplished painlessly.

It is not only in eastern Europe that the sugar-beet crop faces enormous challenges in the future. Research workers everywhere are attempting to improve the economics of beet growing, minimise any threat which it poses to the environment and find other sources of income from the crop. Improved profitability has always been a major research objective, and this book contains numerous examples of attempts to increase yields, decrease inputs, and minimise root impurities and dirt tares. The environmental acceptability of the crop is aided by the fact that it is a most effective scavenger of nitrogen fertiliser, leaving little in the soil at harvest to then escape into the groundwater; work on resistant varieties, biological control and pesticide seed treatments will all help to reduce or dispense completely with the use of pesticides. By-products of the crop (tops, insoluble root

material and molasses) are extensively used as animal feeds (and, to a small degree, in human dietary fibre), in contrast with sugar cane, where the principal by-product (bagasse) is used simply as a fuel in the factory.

Many attempts have been made to find new uses for sugar – most notably in the production of ethylene to be used either as a fuel or as a feed-stock for the chemical industry. Although this process, using cane sugar, is now a well-established industry in Brazil, it is usually uneconomic in developed countries. Its use as a carbon source for the production of chemicals is limited both by economic factors and by the lack of a suitable, cheap organic solvent. However, sucrose is currently used in the manufacture of a range of potentially high-volume products (e.g. polyurethane foams) and high-value, low-volume products (e.g. high intensity sweeteners, vitamins and antibiotics). The search for new markets will continue.

Finally, the exciting developments in genetic engineering, already being exploited to improve beet quality and transfer resistance to herbicides, pests and diseases, could result in sugar-beet plants which will be used in the manufacture of products such as biodegradable plastics or modified carbohydrates.

International co-operation between the scientists who carried out much of the research upon which today's crop is based has been helped by two organisations: the Institut International de Recherches Betteravières (IIRB) in Europe, and the American Society of Sugar Beet Technologists (ASSBT) in the USA. The camaraderie fostered by the meetings, study groups and publications of these organisations extends not only to research workers but includes growers, processors and other sections of the agricultural industry. It has resulted in the development of a cohesive community which is probably unequalled in other crop-based areas of research.

In this book we have attempted to emulate the success of these organisations by inviting workers from industry, research stations and universities, both in Europe and the USA to contribute chapters on various aspects of sugar-beet production and processing. It would be impossible for any of them to give absolutely comprehensive reviews of their subjects, so vast has been the amount of research and development work which has been carried out in the last 200 years. However, we hope that their accounts will give some indication of the achievements which have taken place during that period and perhaps provide a stimulus for the work which lies ahead if the sugar-beet crop is to continue to be competitive in the twenty-first century.

We are grateful to colleagues at Broom's Barn Experimental Station and British Sugar (particularly Marc Allison, Nigel Clarke, Alan Dewar, Michael Durrant, Peter Longden, John Prince and Helen Smith) for reading and commenting on various sections of the book, and to Melanie Allison and Diane Fordham who have expertly and cheerfully produced seemingly endless drafts of the typescript.