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# THE MEDITERRANEAN SUGAR INDUSTRY\*

J. H. GALLOWAY

FOR almost a thousand years North Africa, the Middle East, and Europe received their supplies of sugar from an industry established around the shores of the Mediterranean. This industry began about A.D. 700, for centuries flourished in different parts of the region, and finally succumbed during the sixteenth century to competition from the new plantations in the Americas (Fig. 1). The disappearance of sugarcane from the Mediterranean has been almost complete, leaving few legacies in the present landscape. Some fields of highly subsidized cane are still cultivated behind the tourist beaches of southern Spain near Motril. Ruins of stone sugar mills remain in Palestine and in the deserts of southern Morocco. The Gate of the Sugar Workers in the walls of Syracuse attests to the former importance of sugar cultivation in Sicily. Despite such remainders, the long association of sugar cultivation with the Mediterranean is largely forgotten, and its place in the historical geography of the region is little known.

The Mediterranean is the most northerly part of the world in which sugarcane, a tropical crop, has been successfully cultivated. Hence, it provides an opportunity to study the adaptation of sugar cultivation to marginal environmental conditions. The organization of the Mediterranean industry, as it developed in the fourteenth and fifteenth centuries, heralds the organization of the Atlantic industry. Indeed, the Mediterranean sugar industry can be seen as a school for the colonizers of Madeira, the Canaries, and tropical America. It is an important link in the chain of diffusion and development that has taken sugar from indigenous garden plant in New Guinea to agro-industry in Jamaica, Hawaii, and other parts of the tropical world.

In the standard histories of the Mediterranean in the medieval period, little attention has been given to the growth of the sugar industry. Sugar receives only passing reference as an exotic crop, an object of curiosity to Crusaders, and as an item of trade. Even Fernand Braudel in the most recent edition of his magisterial work on the Mediterranean world of the sixteenth century, gives sugar scant mention.<sup>1</sup> The absence of any comprehensive study of the Mediterranean sugar industry by medievalists has left a gap that historians of sugar have found difficult to fill.<sup>2</sup> Noel Deerr and Edmund von Lippmann, perhaps the most distinguished of these historians, made serious attempts to deal with the medieval period. Deerr's chapter on the

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\* I did much of the reading for this paper during the summer of 1975 at the Department of Geography, University of California, Berkeley. I wish to acknowledge the hospitality of the department. I wish also to thank D. Aidan McQuillan, W. J. Callahan, and D. C. Higgs, colleagues in Toronto, for commenting on earlier versions of the paper. Figures 1 and 2 were drawn in the cartography office of the Department of Geography, the University of Toronto.

<sup>1</sup> Fernand Braudel: *The Mediterranean and the Mediterranean World in the Age of Philip II* (2nd ed.; 2 vols.; William Collins and Co. Ltd., London, 1972-1973).

<sup>2</sup> The medievalist who is possibly the most cited on the topic of sugar in the Mediterranean is the nineteenth-century scholar Wilhelm von Heyd: *Geschichte des Levantehandels im Mittelalter* (2 vols.; J. G. Cotta, Stuttgart, 1879). This is "still the best introduction to the study of medieval spices," according to Robert S. Lopez and Raymond Irving: *Medieval Trade in the Mediterranean World* (Columbia Univ. Press, New York, 1955), p. 108.

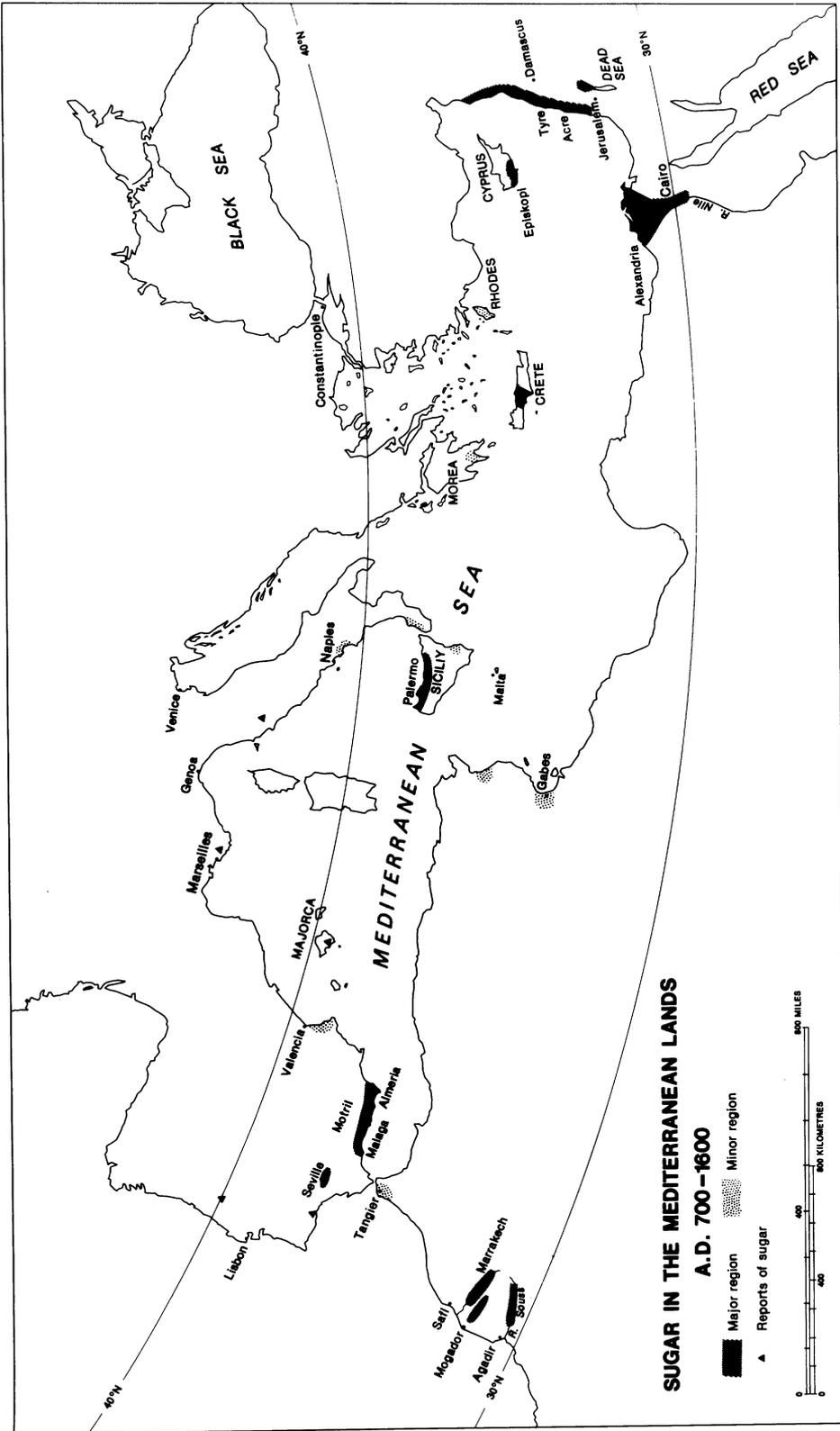


FIG. 1

Mediterranean sugar industry in his "History of Sugar" is still the standard reference in English on the subject even though it was published a quarter of a century ago.<sup>3</sup> Von Lippmann's "Geschichte des Zuckers" is also frequently cited although it was published in 1890 with a second edition in 1929.<sup>4</sup>

New contributions to our knowledge of the Mediterranean sugar industry have come from two types of inquiries. Specialized studies such as Paul Berthier's reconstruction through archaeology of the sugar industry in Morocco have begun.<sup>5</sup> A second source of knowledge is the continuing research on the economic and demographic history of the Mediterranean lands which illuminates the constraints and opportunities encountered by the sugar industry.

Surviving documents lack information on such important matters as the area of land planted in sugarcane, crop yields, production costs, and the amounts of sugar imported and exported. Without quantifiable data, comparisons over time and between areas of production are difficult. The archives have been slow to yield such treasures, and a systematic search for them in the repositories of the Mediterranean lands would be a Herculean, multilingual task. The most important sources are the accounts of sugar cultivation by contemporary travelers and agronomists, both Christian and Muslim, and the references to taxes on sugar, duties, and prices in customs house records and the correspondence of merchants.

My purpose here is to reexamine the Mediterranean sugar industry by drawing on the research published since the days of von Lippmann and Deerr, in order to present a view of the industry as a whole and to trace the antecedents of the plantation economy of the New World. I deal with the introduction of sugar to the Mediterranean, with the techniques of cultivation and manufacture, and with the decline of the industry.

#### ESTABLISHMENT OF SUGAR CULTIVATION

The development of the sugar industry in the Mediterranean is part of an agricultural revolution that took place under the aegis of the Arabs in the years following the founding of Islam (Fig. 2). This revolution was characterized by the cultivation of many crops new to the Mediterranean Basin, by intensification of land use, and by widespread dependence on irrigation. Some of the crops and techniques associated with the revolution had already reached the Mediterranean from the Near East by classical times; in the eighth, ninth, and tenth centuries the Arabs accelerated the westward diffusion of crops and techniques and improved the techniques. Southern Spain emerged as a major locus of this new agriculture; it became a center of diffusion back to North Africa and onto the New World.<sup>6</sup>

<sup>3</sup> Noel Deerr: *The History of Sugar* (2 vols.; Chapman and Hall Ltd., London, 1949-1950), Vol. 1, pp. 73-99.

<sup>4</sup> Edmund Oskar von Lippmann: *Geschichte des Zuckers, seiner Darstellung, seit den ältesten Zeiter. bis zum Beginne der Rübenzucker-Fabrikation* (Hesse, Leipzig, 1890). There is a much-expanded edition (Verlag von Julius Springer, Berlin, 1929).

<sup>5</sup> Paul Berthier: *Les Anciennes Sucreries du Maroc et leurs Réseaux Hydrauliques. Etude Archéologique et d'Histoire Economique. Un Episode de L'Histoire de la Canne à Sucre* (Imprimeries Françaises et Marocaines, Rabat, 1966). This hard-to-come-by work is summarized in a review by Jeanne-Marie Salmi-Bianchi: *Les anciennes Sucreries du Maroc, Annales: Economies, Sociétés, Civilizations*, Vol. 24, 1969, pp. 1176-1180.

<sup>6</sup> For a recent discussion see Andrew M. Watson: *The Arab Agricultural Revolution and Its Diffusion, 700-1100, Journ. Econ. Hist.*, Vol. 34, 1974, pp. 8-35. There is a summary of the course of the revolution in Thomas F. Glick: *Irrigation and Society in Medieval Valencia* (The Belknap Press of Harvard Univ., Cambridge, Mass., 1970), pp. 175-176. For pre-Arab origins of irrigation in Spain see pp. 175-197.

The first references to a sugar industry in the Mediterranean come from Syria, Palestine, and Egypt in the years after their occupation by the Arabs in the first half of the seventh century. Sugar cultivation spread through the valley and delta of the Nile, along the Levant coast as well as into the valley of the Jordan and elsewhere inland where there was water for irrigation.<sup>7</sup> In the second half of the seventh century the Arabs swept across North Africa, reaching Morocco in 682. Deerr and von Lippmann report the arrival of sugar in the western Mediterranean within a few years of the conquest, in accord with the adage that sugar followed the Koran.<sup>8</sup> Although the plant may have traveled quickly, virtually in the baggage trains of the armies, an industry that was dependent on irrigation, technology, and reasonably peaceful times must have developed slowly. Two centuries or so appear to have elapsed between the Arab conquests in the western Mediterranean and the emergence there of a commercial sugar industry.

The earliest references to sugar cultivation in North Africa, southern Spain, and Sicily, which were the most important centers of sugar cultivation established by the Arabs in the West, date from the late ninth and tenth centuries. In North Africa, the first reference to sugar production comes from Morocco and occurs in the work of Abu Hanifa, an author who died in 895.<sup>9</sup> Ibn Hawqal, a tenth-century writer, reported sugar cultivation in North Africa. By the eleventh century, sugar production was established around Gabès and Djalula in Tunisia and around Ceuta in Morocco; the most significant area of production was in southern Morocco in the Sous and neighboring valleys on the flanks of the High Atlas.<sup>10</sup> Spain's first account of a sugar industry is the so-called Calendar of Córdoba, which listed the major activities of the agricultural year and dates from 961, two and a half centuries after the Arabs crossed to Spain. The beginning of the industry should be placed some years earlier than the Calendar, at the opening of the tenth century or even the late ninth century.<sup>11</sup> The Mediterranean coast of Andalucía and the Guadalquivir Valley were the main centers of the industry in Spain, although cane was grown as far north as Valencia.<sup>12</sup> The Arabs first invaded Sicily in 655, but they did not achieve full mastery of the island until 877. There is a record of the export of sugar from Sicily about 900, and Ibn Hawqal described the industry as flourishing half a century later.<sup>13</sup>

The Norman conquest of Sicily in the eleventh century and the Crusades brought northern Europeans into greater contact with the sugar-producing lands. The increased familiarity with sugar among Europeans led to a growth in demand that

<sup>7</sup> Deerr, *op. cit.* [see footnote 3 above], Vol. 1, pp. 74-87, and the references Deerr cites.

<sup>8</sup> *Ibid.*, pp. 79-86; and von Lippman, *op. cit.*, 1929 [see footnote 4 above], pp. 239-240.

<sup>9</sup> Cited in Berthier, *Sucreries du Maroc* [see footnote 5 above], p. 43. Berthier does not fully identify this author, but he is presumably referring to Abu Hanifa al-Dinawari. For a brief comment on this noted scholar, see the "Encyclopaedia of Islam" (4 vols.; E. J. Brill, Leiden and Luzac and Co., London; 1960-1975), Vol. 2, p. 300.

<sup>10</sup> Claudette Vanacker: *Géographie économique de l'Afrique du Nord selon les auteurs du IX siècle au milieu du XII siècle*, *Annales: Economies, Sociétés, Civilisations*, Vol. 28, 1973, pp. 659-680, reference on p. 677 and map 15. For a note on Ibn Hawqal see the *Encyclopaedia of Islam* [see footnote 9 above], Vol. 3, pp. 786-788. Ibn Hawqal was in North Africa and Spain in 947-951 and in Sicily in 973.

<sup>11</sup> R. Dozy and Ch. Pellat: *La Calendrier de Cordoue* (E. J. Brill, Leiden, 1961). See also S. M. Imamuddin: *The Economic History of Spain under the Umayyads, A.D. 711-1031* (Asiatic Soc. of Pakistan, Dacca, 1963), p. 116.

<sup>12</sup> Sugarcane was still being cultivated in southern Valencia in the eighteenth century. It was not manufactured into sugar but was chewed as a refreshment. See Joseph Antonio Cavanilles: *Observaciones sobre la Historia Natural, Geographía, Agricultura, Población y Frutas del Reyno de Valencia (1795-1797)* (2 vols.; Consejo Superior de Investigaciones Científicas, Dept. de Geografía Aplicada del Instituto ELCANO, Zaragoza, 1958), Vol. 2, p. 182.

<sup>13</sup> Deerr, *op. cit.* [see footnote 3 above], Vol. 1, p. 76, and the references he cites.

MAJOR SUGAR PRODUCING AREAS OF THE MEDITERRANEAN

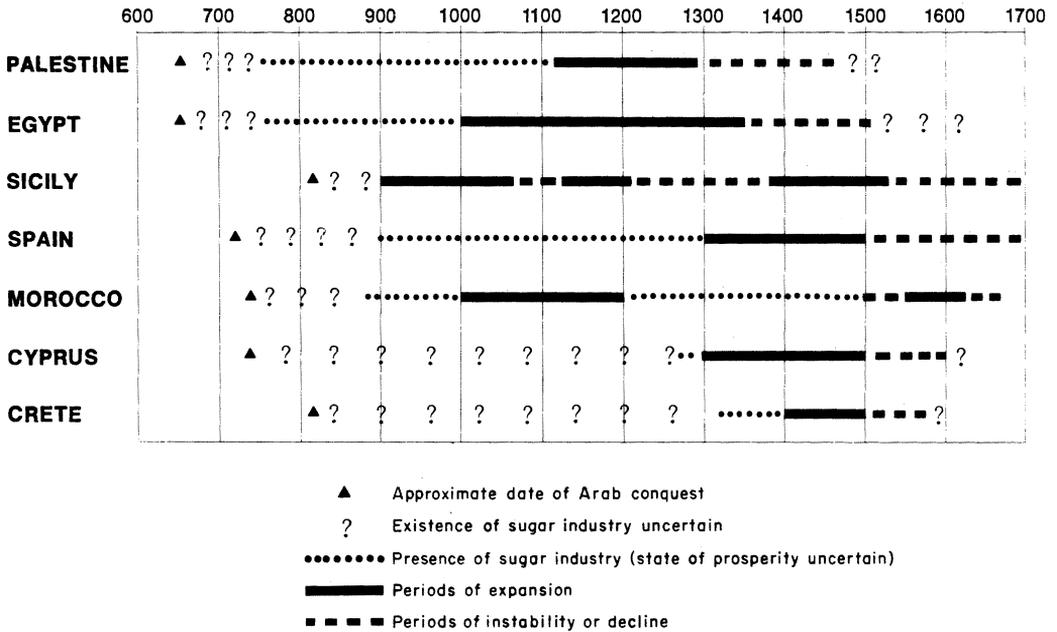


FIG. 2

stimulated an expansion in cultivation in Palestine and the development of sugar industries in Rhodes, Malta, Crete, and Cyprus. The most northerly extension of cultivation occurred in the last years of the industry and was experimental in nature. Early in the fifteenth century the Genoese, encouraged by the Portuguese crown, attempted to establish an industry in the Algarve. In the 1450's cane was reported growing as far north as Coimbra.<sup>14</sup> Tuscany in the 1550's was the scene of a short-lived experiment, while in the 1560's and 1570's Catherine de Medici tried to cultivate sugar in her gardens at Hyères in Provence.<sup>15</sup>

In the thousand-year history of the sugar industry, there probably were few Mediterranean coastal valleys or plains with water for irrigation where sugar was not cultivated. Our knowledge of the existence of minor areas of cultivation depends on the chance survival of documents. For example, we know that sugar was cultivated for a while at least in the Greek Morea and in southern Italy,<sup>16</sup> but we do not have a record of sugar on the southern coast of Turkey, an area equally suited to its cultivation and similar to other parts of the Mediterranean Basin in which it was grown.<sup>17</sup>

<sup>14</sup> Henrique Gomes de Amorim Parreira: *História do Açúcar em Portugal, Anais: Estudos da História da Geografia da Expansão Portuguesa* No. 7, Junta das Missões Geográficas e de Investigações do Ultramar, Lisboa, 1952, pp. 18-19.

<sup>15</sup> Deerr, *op. cit.* [see footnote 3 above], Vol. 1, p. 79 and 85. For Tuscany see also Philip Jones: *Medieval Agrarian Society in Its Prime: Italy*, in *The Cambridge Economic History of Europe* (edited by M. M. Postan; Cambridge Univ. Press, Cambridge, 1966), Vol. 1, pp. 340-431, reference on p. 370.

<sup>16</sup> Deerr, *op. cit.* [see footnote 3 above], Vol. 1, pp. 79 and 83.

<sup>17</sup> Claude Cahen reports sugar in Turkey, but no indication is given of where it was cultivated (Claude Cahen: *Pre-Ottoman Turkey* [Sidgwick and Jackson, London, 1968], p. 158).

## ORGANIZATION OF THE SUGAR INDUSTRY

The organization of resources for sugar production varied around the Mediterranean and changed through time. Uniformity was greatest in the manner of cultivation, where the environment acted as a unifying force, and in the manufacturing of sugar; diversity was most pronounced in the type of labor and in the organization of landholdings.

## CULTIVATION

Sugarcane grows best in hot, sunny climates with abundant rainfall or water for irrigation and where winter temperatures are mild enough to permit continuous growth. The normal period of maturation of the plant is from fourteen to eighteen months. The growth of cane is greatly reduced when root temperatures fall below 21°C (70°F); mild frosts will damage sugarcane and severe frosts will kill it.<sup>18</sup> The Mediterranean is therefore a marginal region for sugar cultivation because its environment is restrictive in two ways. The long summer drought limits cultivation to areas with abundant water for irrigation, and the cool winter months prevent year-round growth. In all of the sugar-growing areas shown on Figure 1, frost is a hazard except in a few favored stretches of the southern coast of Spain. The cooler temperatures and increasing incidence of frost prevented the establishment of sugar industries on the northern rim of the Mediterranean and elsewhere enforced a short growing season. Sugar planted in February and March was harvested in January.<sup>19</sup> A major adaptation for sugar producers was the acceptance of the short growing season and the harvest of what was, by tropical standards, an immature cane with a low sugar content. This poor-quality cane set the Mediterranean industry at a disadvantage when competition from New World producers began.

The fundamentals of sugarcane cultivation have changed little since the thirteenth century.<sup>20</sup> Then, as now, cane was not planted from seed but was reproduced vegetatively: sections of cane several inches long, or setts to use the modern terminology, were planted in furrows in the fields. The medieval cultivators followed the practice known today as ratooning: after a harvest, the roots are left in the ground to produce

<sup>18</sup> There is no reason to suppose that sugarcane in medieval times was more resistant to frost than sugarcane today. Modern sugarcane breeders have failed to produce varieties that frost—except the most mild and shortlived—does not damage. The sugarcane of the medieval Mediterranean industry was a variety of *Saccharum officinarum*. This same variety was taken to tropical America and there became known as Creole cane.

<sup>19</sup> For the dates of planting and harvest see the Calendar of Córdoba, Dozy and Pellat, *op. cit.* [see footnote 11 above], pp. 36, 60, 144, and 172. A later calendar lists sugar only once, at harvest time in January: H. P. F. Renaud: *Le Calendrier d'Ibn al-Bannâ de Marrakech, 1256-1321, Publications de l'Institut des Hautes-Études Marocaines No. 34*, Larose Editeurs, Paris, 1948, p. 30.

<sup>20</sup> Several descriptions of medieval sugar cultivation have come down to us. For an introduction to the medieval Arab writers on agriculture see the article entitled "Filâha (agriculture)" in the *Encyclopaedia of Islam*, *op. cit.* [see footnote 9 above], Vol. 2, pp. 899-910. For writers in Muslim Spain see also S. M. Imamuddin: *Al-Filâhah (Farming) in Muslim Spain, Islamic Studies*, Vol. 1, 1962, pp. 51-89, esp. pp. 54-59. Possibly the most comprehensive source of information on agriculture in Muslim Spain is Ibn al-Awwam: *Libro de Agricultura* (2 vols.; Imprensa Real, Madrid, 1802). The text is printed in Arabic and Spanish. The discussion of sugar is in Vol. 1, pp. 390-393. Deerr (*op. cit.* [see footnote 3 above], Vol. 1, pp. 80-81) reprints in English Ibn al-Awwam's remarks on sugar. The translation from the Spanish is not entirely faithful. The most important authorities on the Egyptian sugar industry are al-Makrisi (A.D. 1364-1442) and al-Nuwairi (A.D. 1279-1332). English translations of their descriptions of the sugar industry are given by Deerr, *op. cit.* [see footnote 3 above], Vol. 1, pp. 88-92. There is also Mounira Chapoutet-Remadi: *L'Agriculture dans L'Empire Mamluk au Moyen-Age d'après al-Nuwairi, Les Cahiers de Tunisie*, Vol. 22, 1974, pp. 23-45, reference on pp. 31-35.

one or more additional crops. Yields of ratoon crops eventually decline until the time comes to clear the fields and replant.<sup>21</sup>

Medieval accounts of sugar cultivation suggest that experimentation in sugar cultivation was part of the Arab agricultural revolution. The Arab cultivators had tried different methods of planting cane and made recommendations on the spacing of setts in the fields and on the depth of the furrows. They knew that to improve the germination of setts, the setts should be covered with soil and stored, in readiness for planting.<sup>22</sup> They had investigated closely the importance of manuring. In Spain, the manure of sheep, mules, asses, doves, and other animals and birds was considered to have distinctive merits appropriate to different crops and soils. The manure was applied directly to the soil or placed in the irrigation channels to be spread by the water.<sup>23</sup> Understandably, a concern for irrigation pervades the Arab accounts. Water was to be applied every few days. In Spain the recommended frequency varied in part at least with the stage of growth of the cane, whereas in Egypt cane was irrigated twenty-eight times between planting and harvest.<sup>24</sup>

Despite the advances made in sugar cultivation through experimentation in planting, manuring, and irrigation, the major handicap for sugar—the winter—could not be overcome. A description from sixteenth-century Sicily suggests that an attempt was made to lengthen the growing season by starting cane in protected nursery beds. Setts were placed in compost and after germination transplanted to the fields. These setts were cut from the top of the cane stems, for the buds higher on the stem germinate more quickly than those lower down.<sup>25</sup> Ibn al-Awwam wrote of “planting cane from its roots,” an imprecise phrase that could refer to ratooning but might also be an allusion to the transplanting of young cane from nurseries.<sup>26</sup> The breeding of cane to produce new varieties with greater tolerance for cold weather or with the ability to mature more quickly was beyond the scope of the medieval agronomists. The discovery that cane can carry fertile seed and the beginning of selective breeding date only from the nineteenth century. Even so, the medieval agronomists advised cultivators to select the setts carefully, and over the centuries this selection may have resulted in the gradual improvement in the quality of cane.

The early years of the Mediterranean industry probably witnessed a greater measure of experimentation in sugar cultivation than any subsequent period in the history of sugar until the nineteenth century. Unfortunately, the surviving records do not provide a measure of the improvement in yields that this attention to the techniques of cultivation achieved.<sup>27</sup>

<sup>21</sup> A comment by Ibn al-Awwam suggests that in southern Spain three harvests were cut from the same roots: the initial crop and two ratoon crops (Ibn al-Awwam, *op. cit.* [see footnote 20 above], Vol. 1, p. 392).

<sup>22</sup> A modern authority on sugar cultivation has written: “Cane for planting should be kept in small heaps covered lightly with trash for a few days before being planted. This well-known practice improves germination” (A. C. Barnes: *The Sugar Cane* [2nd edit.; Leonard Hill Books, Aylesbury, England, 1974], p. 270).

<sup>23</sup> For manuring in Muslim Spain see Lucie Bolens: *Engrais et protection de la fertilité dans l’agronomie andalouse hispano-arabe XIe–XIIe siècles*, *Etudes Rurales*, Vol. 46, 1972, pp. 34–60.

<sup>24</sup> For a discussion of irrigation see Lucie Bolens: *L’eau et l’irrigation d’après les traités d’agronomie andalouse au Moyen-Age (XIe–XIIIe siècles)*, *Options Méditerranéennes*, Vol. 16, 1972, pp. 65–77.

<sup>25</sup> Deerr, *op. cit.* [see footnote 3 above], Vol. 1, pp. 78–79, quoting a Sicilian source whom he cites as Carusio: *Bibliotheca Sicular* (Palermo, 1723), p. 8. See also Barnes, *op. cit.* [see footnote 22 above], p. 258.

<sup>26</sup> In the modern sugar industry, nurseries are used in experimental stations to propagate quickly new varieties of cane and on plantations to grow cane for setts (Barnes, *op. cit.* [see footnote 22 above], pp. 265–266 and 270).

<sup>27</sup> For a discussion of sugar cultivation today in northern regions see Helmut Blume: *El Cultivo de la*



FIG. 3—A Sicilian sugar factory of the second half of the sixteenth century. Source: Jan van der Straet: *Nova Reperta* [1570] (Philippus Gallaeus, Antuerpiae, 1600), plate XIII. (Reproduced by permission of the British Library Board.)

#### MILLING AND MANUFACTURE

In contrast to experimentation in cultivation, the milling and manufacture of sugar in the medieval Mediterranean changed little. Thus the region was aptly characterized as one of “technological retardation,” compared with northern Europe.<sup>28</sup> The mills and presses used to extract the juice from the cane were adapted from those already used around the Mediterranean to mill flour, to extract oil from olives, or to crush grapes and other fruits. The work of milling was labor intensive and, given the nature of the equipment, inefficient.<sup>29</sup> The cane stems were chopped into pieces several inches long and crushed at least twice. The cane was milled, and then the residue, sometimes packed into sacks, was transferred to a press.

The mills were generally of two types. One type consisted of an upper rotating grindstone set over a lower immobile one. The pieces of cane were ground between

Caña de Azucar en Andalucia, comparado con el cultivo de la caña en Luisiana, *Estudios Geográficos*, Vol. 19, 1958, pp. 87–112; and for northern India and Pakistan see Barnes, *op. cit.* [see footnote 22 above], pp. 52–53 and 85–89.

<sup>28</sup> Lynn White: *Medieval Technology and Social Change* (The Clarendon Press, Oxford, 1962), p. 88.

<sup>29</sup> R. J. Forbes: *Food and Drink*, in *History of Technology* (edited by Charles Singer, E. J. Holmyard, A. A. Hall, and T. J. Williams; 5 vols.; Clarendon Press, Oxford, 1954–1958), Vol. 2, pp. 103–146; Sherwood Taylor and Charles Singer: *Pre-Scientific Industrial Chemistry*, in *ibid.*, pp. 347–374; and R. J. Forbes: *Power*, in *ibid.*, pp. 589–622. Also F. M. Feldhaus: *Die Maschine in Leben der Völker* (Verlag Birkhauser, Basel-Stuttgart, 1954), pp. 186–187. Discussion of Mediterranean sugar mills finds disappointingly little space in the standard histories of technology.

the two stones. The second type is known in the literature as the "edge-runner." This consisted of a wheel-shaped grindstone set upright in a shallow depression in which the cane was placed. Protruding horizontally from the center of the wheel and extending out beyond the rim of the depression was a driveshaft. Men or animals turned the wheel around the depression, thereby crushing the cane. The "edge-runner" had a long life in the sugar industry, for it was taken to the New World where it survived for some time.<sup>30</sup> The final extraction of the juice was carried out by either beam or screw presses. Beam presses could consist of a single beam or trunk of wood that was winched or screwed down onto the cane, which was placed beneath the beam on a stone surface. Screw presses consisted of a series of boards, one atop the other. Cane was inserted between the boards, and the whole tightened by the turning of a screw or screws. Other simpler and probably less effective methods of extracting juice existed, such as the mortar and pestle described by Crusaders in Palestine.<sup>31</sup> In seventeenth-century Spain there were small sugar mills consisting of two horizontal rollers between which the cane was passed, but the extent of earlier use is not known.<sup>32</sup> Such mills are still used to crush cane in many isolated parts of the tropical world. The most detailed description of milling in the medieval Mediterranean is Al-Nuwairi's account of work in an Egyptian mill,<sup>33</sup> and an engraving survives of a sugar factory in Sicily in 1570 (Fig. 3). In the foreground of this engraving there is a watermill; in the rear, a screw press.

The few instances of technological innovation in sugar milling during the Mediterranean era are poorly documented and, in one major instance, controversial. E. Ashtor considers that the substitution of horses for oxen in the mills in the Christian countries led to improved efficiency, which helped to give the western Mediterranean a competitive edge over the Levant.<sup>34</sup> The substitution was gradual: Ashtor does not date its beginning but considers that it was complete by about 1400. His conclusion may be too sweeping because horses did not entirely replace oxen as work animals around the Mediterranean, and because oxen were an important source of power in the sugar mills of the New World. The application of waterpower to sugar milling was much more significant than the substitution of horses for oxen. The use of waterpower in the sugar mills became widespread, particularly in Palestine, Egypt, Morocco, and Sicily. It was used in sugar mills built by the Crusaders, though it is not known whether they were the first to use waterpower for milling sugar in Palestine.<sup>35</sup> Al-Nuwairi mentions waterpowered sugar mills in Egypt. Berthier identified fourteen sugar factories in southern Morocco that employed waterpower. He has also traced the routes of the aqueducts from the Atlas Mountains, but has been unable so far to date the construction of the mills.<sup>36</sup> A well-designed water mill made the crushing of

<sup>30</sup> Deerr (*op. cit.* [see footnote 3 above], Vol. 2, p. 235) uses the term "edge-runner." He reproduces an illustration of an edge-runner in use in a sugar mill in Brazil. In addition to sugar, edge-runners were used to crush products as diverse as olives and ore.

<sup>31</sup> See the account of Albert von Aachen, cited by Jakob Baxa and Guntwin Bruhns: *Zucker Im Leben Der Völker, Eine Kultur-und Wirtschaftsgeschichte* (Verlag Dr. Albert Bartens, Berlin, 1967), p. 9.

<sup>32</sup> Deerr, *op. cit.* [see footnote 3 above], Vol. 2, p. 536.

<sup>33</sup> See *ibid.*, Vol. 1, pp. 90-92 for al-Nuwairi's account. See also Chapoutet-Remadi, *op. cit.* [see footnote 20 above], pp. 32-34.

<sup>34</sup> E. Ashtor: *Levantine Sugar Industry in the Late Middle Ages, A Sample of Technological Decline* (unpublished paper given at the Princeton Conference on The Economic History of the Near East, Princeton, N. J., 1974), p. 17.

<sup>35</sup> The ruins of two of these mills still stand, one near Jericho, the other near a-Safi (Meron Benvenisti: *The Crusaders in the Holy Land* [Israel Univ. Press, Jerusalem, 1970], p. 254).

<sup>36</sup> Berthier, *Sucreries du Maroc* [see footnote 5 above], pp. 111, 133-144, and maps.

sugarcane more efficient, but even the use of waterpower did not necessarily eliminate the second stage of extraction in the presses, as the Sicilian mill demonstrates.

Another important invention in the technology of sugar production was the three-cylinder mill. It was, perhaps, the first mill designed specifically for sugar, and it was powered by horses, oxen, wind, or water. The cylinders, or presses, in this mill were set vertically and the cane stems were passed between the rotating cylinders. The advantage of the mill was that it greatly reduced the amount of labor required. It was no longer necessary to chop the cane stems into small pieces before milling. A small three-cylinder mill could be operated by as few as three people, one on either side of the mill to pass the cane back and forth with a third to coax along the oxen or horse which provided the power. The three-cylinder mill became the standard mill of the colonial industry in the Americas (Fig. 4).

There are two schools of thought concerning the origins of the three-cylinder mill in the historical geography of sugar production. Von Lippmann credits the invention to Pietro Speciale of Sicily in 1449, a point of view that has been adopted by Deerr and other modern scholars.<sup>37</sup> The invention of this mill has been cited as a cause of the revival of the Sicilian sugar industry in the late fifteenth century<sup>38</sup> and as an example of the technological superiority of the western Mediterranean sugar industry over that of the Levant.<sup>39</sup> According to the other point of view, the invention first appeared in Peru and was subsequently adopted in Brazil between 1608 and 1612.<sup>40</sup>

The controversy continues, with criticism focusing on the authenticity of the Speciale claim to the invention. The sources cited by von Lippmann and Deerr in support of the Speciale claim are two nineteenth-century Sicilian authors, Rosario Gregorio and Gaspar Vaccaro e Panebianco.<sup>41</sup> Moacyr Pereira, a Brazilian scholar, examined the writings of Gregorio and Vaccaro as well as the sources that they drew on, but he did not find any evidence of a three-cylinder mill. Speciale, a Sicilian official, did encourage the development of the sugar industry and built a mill or *trappeto*, but, according to Pereira, it was not the three-cylinder type. Pereira concluded that von Lippmann and Deerr misinterpreted their sources, the confusion perhaps arising over the meaning of *trappeto*, a word that has been applied to different types of mills.<sup>42</sup> Further doubts about the Speciale claim are raised by the fact that the three-cylinder mill is not reported elsewhere in the Mediterranean. Had it

<sup>37</sup> Von Lippmann, *op. cit.*, 1929 [see footnote 4 above], p. 338; and Deerr, *op. cit.* [see footnote 3 above], Vol. 1, p. 77; and Vol. 2, p. 535. Deerr does not cite von Lippmann but cites the same sources. For recent statements see, for instance, Baxa and Bruhns, *op. cit.* [see footnote 31 above], p. 16; Ward Barrett: *The Sugar Hacienda of the Marquesas del Valle* (Univ. of Minnesota Press, Minneapolis, 1970), p. 53; and Charles Verlinden: *The Beginnings of Modern Colonization* (Cornell Univ. Press, Ithaca and London, 1970), p. 20.

<sup>38</sup> Verlinden, *op. cit.* [see footnote 37 above], p. 20.

<sup>39</sup> Ashtor, *Levantine Sugar* [see footnote 34 above], p. 17.

<sup>40</sup> Frédéric Mauro: *Le Portugal et L'Atlantique au XVII<sup>e</sup> Siècle, 1570-1670: Etude économique* (S.E.V.P.E.N., Paris, 1960), p. 204 with facing illustration from the archives of the Ajuda Place, Lisbon; and most recently Guillermo Cespedes: *Latin America: The Early Years* (Alfred A. Knopf, New York, 1974), p. 37. Among Brazilian writers, see Luis Amaral (*História Geral da Agricultura Brasileira* [2nd edit.; Companhia Editôra Nacional, São Paulo, 1958], Vol. 1, p. 334), who quotes, with a caution, Frei Vicente do Salvador as his source.

<sup>41</sup> Rosario Gregorio: *Opere scelte degli zuccheri Siciliani* (Tipografia di Pietro Pensante, Palermo, 1845); and Gaspar Vaccaro e Panebianco: *Sul richiano della canna zuccheriora in Sicilia* (2 vols.; Tipografia di Lipomi, Palermo and Girgenti, 1835-1826).

<sup>42</sup> Moacyr Soares Pereira: *A Origem dos Cilindros na Moagem da Cana: Investigação em Palermo* (Instituto do Açúcar e do Alcool, Rio de Janeiro, 1955). Pereira reprints in his monograph the relevant passages from Gregorio and Vaccaro.



FIG. 4—A three-cylinder mill in a West Indian sugar factory. Source: Pierre Pomet: *Histoire Générale des Drogues* (J.-B. Loyson, Paris, 1694), p. 94. (Reproduced by permission of the British Library Board.)

been invented in Sicily in 1449 it is reasonable to expect that it would have spread rapidly because of its advantages over other types of mills.<sup>43</sup> Deerr consequently was forced into the awkward argument that the late sixteenth-century Sicilian mill shown in Figure 3 is an anachronism.<sup>44</sup>

Although the origins of the three-cylinder mill still remain clouded, the invention marked a major advance in the first stage of manufacturing sugar—the extraction of the juice from the sugarcane. The next step is the reduction of the cane juice by boiling it into a thick syrup which, on cooling, separates into crystals and molasses. In the Mediterranean industry, the juice was boiled in cauldrons set over furnaces that consumed large amounts of fuel. At this stage in the manufacture of sugar, fuel supply for the furnaces was of critical importance.

Even by the time of the Arab conquests, the Mediterranean forest had already been heavily depleted. Deforestation, with the resulting shortage of timber, was particularly acute in the southern Muslim lands. The progress of industries, such as metallurgy and the manufacture of pottery, glass, and sugar, that required fuel was severely curtailed.<sup>45</sup> Berthier, for example, has attributed the absence of sugar cultiva-

<sup>43</sup> Carmelo Trasselli, the modern historian of the Sicilian sugar industry, does not mention the invention of a three-cylinder mill. See Carmelo Trasselli: *Producción y Comercio de Azúcar en Sicilia del Siglo XIII a XIX*, *Rev. Bimestre Cubana*, Vol. 72-73, 1957, pp. 130-154.

<sup>44</sup> Deerr, *op. cit.* [see footnote 3 above], Vol. 2, p. 535.

<sup>45</sup> Maurice Lombard: *Un Problème Cartographié: Le Bois dans la Méditerranée Musulmane (VII<sup>e</sup>-XI<sup>e</sup> Siècles)*, *Annales: Economies, Sociétés, Civilisations*, Vol. 14, 1959, pp. 234-254, esp. p. 250. See also Maurice Lombard: *Arsenaux et Bois de Marine dans La Méditerranée Musulmane (VII-XI Siècles)*, *2nd Colloque Internationale d'Histoire Maritime, 1957: Le Navire et L'Economie Maritime du Moyen-Age au XVIII<sup>e</sup> Siècle Principalement en Méditerranée*, S.E.V.P.E.N., Paris, 1958, pp. 53-99.

tion from some of the irrigable valleys in Morocco to the lack of timber for fuel.<sup>46</sup> The scarcity and expense of fuel helped ensure that sugar remained a luxury item.

The final stages in sugar manufacturing were the crystallization of the cane juice and the purification of the crystals. After boiling, the concentrated cane juice was poured into inverted earthenware cones to cool, crystallize, and for the molasses to drain. The molasses could be reboiled to produce more sugar. The finest quality sugar was made by dissolving in water the crystals from the first boiling and reboiling and recrystallizing two or three times. Sugar was marketed in a variety of grades, in powder, in lumps, and in loaves. Some sugar was colored and flavored with violets or rose water.<sup>47</sup> In Morocco, and quite probably elsewhere, sugar was "clayed" by placing waterlogged clay over the top of the cones. The water from the clay percolated through the sugar, leaching out the lingering traces of molasses. The whitest sugar came from the top of the cane, next to the clay.<sup>48</sup>

Toward the end of the fifteenth century, there were major changes in the geography of sugar refining. Until the late fifteenth century, sugar was manufactured in the country in which it was grown and was exported as a finished product. After about 1470, however, the imported sugar began to be further refined in Europe, first in Venice and Bologna and later in Antwerp and Holland. During the sixteenth and seventeenth centuries, refineries were built in many cities in Northern Europe. This transfer of part of the manufacturing of sugar from producing country to importing country had a number of results: it transferred employment in the industry from producer to importer; it reduced the producer's interest in making fine quality sugar; and it made the producer subservient to the importer. The development of refining in Europe placed the producer in a dependent or "colonial" relationship with the manufacturer, a relationship that has survived with little change to this day.

#### LAND AND LABOR

The pattern of land tenure and the type of labor employed in the sugar industry varied greatly from one part of the Mediterranean Basin to another, and changed with the passage of time. During the early years of the sugar industry, the organization of land and labor was similar in the Muslim lands of Spain, North Africa, and the Levant. Later, developments in Egypt and Morocco broke this uniformity; the situation was also different in the Christian islands of Crete and Cyprus.

In the Muslim countries the size of landholdings ranged widely. Peasant-owned plots existed side by side with large estates. The estates for the most part were parceled out to tenants who farmed the land as sharecroppers. The percentage of the harvest that the tenants had to surrender to the owners depended on the quality of the land and on the proportion of the total investment in seed and equipment made by the

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<sup>46</sup> Berthier, *Sucreries du Maroc* [see footnote 5 above], p. 81. Berthier did investigate, albeit inconclusively, the possibility that the residue of the sugarcane after milling—the bagasse—was used as fuel. There is indeed no indication in the literature that bagasse was used for fuel in the Mediterranean industry as it was in tropical America when wood became scarce. This contrast may be explained by differences in milling. The long stems of cane emanating from three-cylinder mills made an acceptable fuel, but the chopped and pulped bagasse of the Mediterranean mills did not.

<sup>47</sup> There is a description of the types of sugar produced in the eastern Mediterranean in Francesco Balducci Pegolotti: *La Practica della Mercatura* (edited by Allan Evans; Medieval Acad. of America, Cambridge, Mass., 1936), pp. 362–365 and 434–435. An English translation of Pegolotti's list of types of sugar appears in Lopez and Irving, *op. cit.* [see footnote 2 above], pp. 109–114.

<sup>48</sup> Berthier, *Sucreries du Maroc* [see footnote 5 above], pp. 193–201. The manufacture of "clayed" sugar became widespread in the Americas.

landowners and tenants. Only a small amount of land was held as demesne, land that the owners undertook to cultivate by drawing on the labor of a serf class. Indeed, *corvée* and slave labor were rare; the agricultural work was done by tenants, their families, and even hired hands. Whether, in this mix of landholdings, sugar was exclusively an estate crop or was also grown on peasant holdings remains obscure.<sup>49</sup> In Spain this pattern of rural organization appears to have been long-lasting.<sup>50</sup> It survived in the Levant at least until the end of Crusades.<sup>51</sup> In the Crusader states, the land passed into the ownership of western feudal nobles, of military orders such as the Knights of St. John, of the church and of Italian merchant cities,<sup>52</sup> but continuity with Muslim agricultural tradition was maintained. Sugar, however, perhaps because of the large capital investment it required, was grown on the demesne land and a *corvée* was levied on the peasantry to provide the labor.<sup>53</sup>

The history of land tenure and agricultural labor in both Egypt and Morocco is difficult to unravel, but it is clear that the approach to land management differed from that in other Muslim countries. More information is available on Egypt than on Morocco. In Egypt, in Mamluk times (1250–1517), the land was controlled by the state—or more precisely, by the sultan—and divided into estates known as *iqta's*. The sultan awarded these to Mamluk military officers. The *iqta's* were not hereditary, and the revenue of the *iqta's* was gauged to the rank of the officer. The officers lived in Cairo, leaving the management of the *iqta's* to agents. Cultivation was done by peasants who paid a tax or a portion of the crop to the grantee. *Corvée* in Mamluk Egypt was rare, but it was used in the cultivation of sugar.<sup>54</sup> The record of landownership in Morocco is almost completely lost. Berthier concludes that the sugar industry was a state monopoly and that the state farmed out the management of the mills and estates. The record is also incomplete on the type of labor employed. Berthier accepts that there was a slave labor force in the sugar industry. His evidence for slavery is in part based on place names: names of several locations in the valleys in which sugar was cultivated incorporate the word “slave.” The development of the slave trade, Berthier concludes, was one of the motives for the Moroccan trans-

<sup>49</sup> For a description of the early Islamic estate, see Watson, *op. cit.* [see footnote 6 above], pp. 29–30.

<sup>50</sup> For a discussion of sharecropping arrangements in Spain: S. M. Imamuddin, *op. cit.* [see footnote 20 above], pp. 60–64; E. Lévi-Provençal: *Histoire de l'Espagne Musulmane* (Editions G-P Maisonneuve et Larose, Paris, 1967), Vol. 2, pp. 267–268; and Jaime Vicens Vives, con la colaboración de Jorge Nodal Oller: *Manual de Historia Económica de España* (4th edit.; Editorial Vicens-Vives, Barcelona, 1965), pp. 102–103. There is a succinct discussion of the status of slaves in Spain in Robert Ignatius Burns: *Islam under the Crusades: Colonial Survival in the Thirteenth Century Kingdom of Valencia* (Princeton Univ. Press, Princeton, N.J., 1973), pp. 109–110.

<sup>51</sup> Many of the general histories of the Crusades contain disappointingly little on agriculture. I found useful Joshua Prawer: *The Latin Kingdom of Jerusalem: European Colonialism in the Middle Ages* (Weidenfeld and Nicolson, London, 1972); Jonathan Riley-Smith: *The Feudal Nobility and the Kingdom of Jerusalem, 1174–1277* (MacMillan, London, 1973); and Claude Cahen: *La Syrie du Nord à l'Époque des Croisades et La Principauté Franque d'Antioche* (Librairie Orientaliste Paul Geuthner, Paris, 1940).

<sup>52</sup> See especially Jonathan Riley-Smith: *The Knights of St. John in Jerusalem and Cyprus c. 1050–1310* (Macmillan, London, 1967); Joshua Prawer: *Étude de Quelques Problèmes Agraires et Sociaux d'Une Seigneurie Croisée au XIII<sup>e</sup> Siècle, Byzantion*, Vol. 22, 1952, pp. 5–61; and Vol. 23, 1953, pp. 143–170, reference on pp. 30–31; and for an example of sugar cultivation on church estates see D. H. Williams: *Cistercian Settlement in the Lebanon, Cîteaux, Comentarîi Cistercienses*, Vol. 25, 1974, pp. 61–74, reference on p. 73.

<sup>53</sup> Riley-Smith, *Feudal Nobility* [see footnote 51 above], p. 46; and Prawer, *Problèmes Agraires et Sociaux* [see footnote 52 above], p. 165.

<sup>54</sup> A. N. Poliak: *La Féodalité Islamique, Rev. des Etudes Islamique*, Vol. 10, 1936, pp. 247–265, reference on p. 262. For a discussion of the *iqta'* system see Hassanein Rabie: *The Financial System of Egypt, A.H. 564–741/A.D. 1169–1341* (Oxford Univ. Press, London, New York, and Toronto, 1972), pp. 26–72.

Saharan expeditions of the late sixteenth century.<sup>55</sup>

Estates on Crete and Cyprus differed from those in Muslim countries in that demesne land was much more extensive and the *corvée* was an important source of labor.<sup>56</sup> During the fourteenth and fifteenth centuries, agricultural labor on these islands was scarce because of the ravages of war and plague. A response to this shortage was the increasing use of slave labor. Even before the Black Death in 1348, slaves were being imported to Crete and Cyprus, but later slavery became even more significant. The slaves were from varied national backgrounds: Greeks, Bulgarians, Turkish prisoners of war, and Tartars brought from the shores of the Black Sea.<sup>57</sup>

As the organization of the Mediterranean sugar industry evolved, the antecedents of plantation agriculture can be recognized. The cultivation of sugar in many parts of the Mediterranean employed forced labor, at first *corvée* and later also slave labor. The link between sugar cultivation and slavery which was to last until the nineteenth century became firmly forged in Crete, Cyprus, and Morocco. In addition to forced labor, there were other harbingers of plantation agriculture in the Christian-ruled lands of the eastern Mediterranean. For example, a colonial relationship was established between the primary producing, cane-growing areas and the metropolitan, manufacturing, and refining centers of Europe. Crete and Cyprus became colonies. Crete passed under Venetian rule in 1204, and Cyprus became a Venetian possession in 1489. Venice encouraged the agricultural development of its colonies in the eastern Mediterranean and looked to them for supplies of wheat, wine, raisins, and other products in addition to sugar.<sup>58</sup> In the fourteenth and fifteenth centuries, sugar increased in importance, especially in Cyprus, and large estates were devoted to it. One example is the estate of the Cornaro family at Episkopi which in 1449 was reported to be employing 400 laborers in the production of sugar.<sup>59</sup> Given the fame and wealth of the Cornaro family,<sup>60</sup> this estate was probably atypically large, but nevertheless indicates that at least one Mediterranean sugar estate was comparable in terms of numbers of workers to the largest plantations of tropical America.

#### THE LAST PHASE, A.D. 1300—A.D. 1600

The decline of the Mediterranean sugar industry has traditionally been attributed to competition from more efficient producers in the new European colonies in the Atlantic and in America. Madeiran sugar began to reach Europe after 1450, and by 1500 was being distributed throughout western Europe, finding markets even as far east as Constantinople and Chios, the Genoese colony and entrepôt off the coast of

<sup>55</sup> Berthier, *Sucreries du Maroc* [see footnote 5 above], pp. 224–229 and 240–242; and Paul Berthier: *Les Plantations de Cane à Sucre dans L'Ancien Maroc, Hespéris-Tamuda*, Vol. 7, 1966, pp. 33–40, references on pp. 37 and 40. There were expeditions in 1591 and 1592.

<sup>56</sup> Riley-Smith, *Knights of St. John* [see footnote 52 above], p. 105.

<sup>57</sup> There is a discussion of labor problems in the Venetian possessions in Freddy Thiriet: *La Condition Paysanne et Les Problèmes de L'Exploitation Rurale en Romanie Greco-Vénitienne, Studi Veneziani*, Vol. 9, 1967, pp. 35–69; and for slavery in the eastern Mediterranean see Verlinden, *op. cit.* [see footnote 37 above], pp. 26–32.

<sup>58</sup> Freddy Thiriet: *La Romanie Vénitienne au Moyen Age: Le développement et l'exploitation du domaine colonial vénitienne, (XII–XV siècles), Bibliothèque des Ecoles Françaises d'Athènes et de Rome*, Editions E. de Boccard, Paris, 1959.

<sup>59</sup> This example has been frequently cited in the literature: von Heyd, *op. cit.* [see footnote 2 above], 1923 edit., Vol. 2, p. 687; Deerr, *op. cit.* [see footnote 3 above], Vol. 1, p. 84; and Verlinden, *op. cit.* [see footnote 37 above], pp. 19–20. Sir Charles Hill (*A History of Cyprus* [3 vols.; Cambridge Univ. Press, Cambridge, 1948], Vol. 2, p. 816) gives 1494 as the date of the reference.

<sup>60</sup> The Cornaros were of Venetian origin. The last Queen of Cyprus was a member of the family.

Asia Minor.<sup>61</sup> Sugar from São Tomé first appeared in Europe during the 1490's, and Brazilian sugar began to arrive in the 1530's and 1540's.<sup>62</sup> The traditional explanation of the decline of the industry appears overly simplified when set against the changing geography of sugar cultivation during the last phase of the Mediterranean industry. The production of sugar decreased in importance in Egypt, Palestine, and Syria during the fourteenth century; and there was a subsequent increase in production in Cyprus, Crete, and the western Mediterranean. The final collapse of the industry throughout the Mediterranean did not come until the late sixteenth century. The decline of the sugar industry in the eastern Mediterranean began more than a century before, and the industry in the west flourished for more than a century after Madeiran sugar first appeared on the scene. To account for the early decline of the industry in the east and for its ultimate collapse in the west, factors other than competition must also be considered; they are warfare, plague, the policies of the Mamluk sultans of Egypt, technological stagnation, and the deterioration of the environment.

Egypt, Palestine, and Syria, the three countries that had been important suppliers of sugar to western Europe, were importing sugar from the west by the end of the fifteenth century—a reversal of earlier trading patterns.<sup>63</sup> The decrease in the number of sugar refineries in Egypt is indicative of the change: there were sixty-six refineries in Fustat (Old Cairo) in 1324; a century later only nineteen were functioning, the others having been abandoned or converted to new uses.<sup>64</sup> Other forms of agriculture suffered along with sugar cultivation. Debate continues over the cause of this prolonged decline in agriculture and prosperity. Warfare is a readily available explanation. During the second half of the thirteenth century, the Crusader states in Syria and Palestine were finally conquered. The Crusader wars were followed by the Mongol invasions that culminated in the ravages of Tamerlane in 1400. In the fifteenth century, the Ottoman Turks extended their power. Inevitably these wars in the eastern Mediterranean were destructive to agriculture and trade.

However, warfare was not the sole or even the most significant cause of the decline. Some scholars have blamed the decline of Egyptian agriculture on the policies of the Mamluks, who were rapacious and corrupt. Mamluk misrule led to the weakening of government authority in the countryside. The bedouin of the desert exploited this situation by plundering the cultivated areas. The peasants fled to the cities and left their land untended. These developments in turn resulted in a fall in the revenues of the *iqta's*. The Mamluks sought to remedy this loss in their income by raising taxes on commerce and by establishing monopolies in the most profitable trades, including sugar. Inefficient and corrupt administration of the monopolies further impeded agriculture. Al-Makrisi, a contemporary witness, appears to have been the originator of this explanation of the decline of Egyptian agriculture, and he has been followed by

<sup>61</sup> Virginia Rau and Jorge de Macedo: *O Açúcar Da Madeira Nos Fins do Século XV: Problemas de Produção e Comércio* (Junta-Geral do Distrito Autónomo do Funchal, Funchal, 1962), pp. 12-16; and Jacques Heers; *Gênes au XV<sup>e</sup> Siècle, S.E.V.P.E.N.*, Paris, 1961, pp. 495-497. Sugar was also cultivated in the Canaries and the Azores.

<sup>62</sup> For sugar cultivation on São Tomé see Francisco Tenreiro: *A Ilha de São Tomé, Memórias da Junta de Investigações do Ultramar*, Vol. 24, Junta de Investigações do Ultramar, Lisboa, 1961, pp. 67-74; and Parreira, *op. cit.* [see footnote 14 above], p. 58.

<sup>63</sup> The export of western sugar to Chios and Constantinople has been noted above. See also Eliyahu Ashtor: *Histoire des Prix et des Salaires dans l'Orient Médiévale* (S.E.V.P.E.N., Paris, 1969), p. 384.

<sup>64</sup> Abraham Udovitch: *Egypt, part of Robert Lopez, Harry Miskimin and Abraham Udovitch: England to Egypt, 1300-1500: Long-Term Trends and Long-Distance Trade, in Studies in the Economic History of the Middle East* (edited by M. A. Cook; Oxford Univ. Press, London, 1970), pp. 115-128, reference on p. 116.

some modern scholars.<sup>66</sup> Recently, this interpretation of Mamluk Egypt has been questioned. The revisionist explanation reverses the line of argument: the Mamluk policies were not the cause of the decline, but a response to depopulation brought about by plague.<sup>66</sup>

The Black Death, which reached Egypt in the fall of 1347, was one of a series of plagues that struck there in the fourteenth and fifteenth centuries.<sup>67</sup> By the early 1400's, the population of Egypt may have been reduced by as much as a third. Other factors contributed to the population loss. Marked fluctuations in the level of the Nile as well as the poor maintenance of the irrigation system contributed to crop failures and famine. Evidence also points to a cattle murrain at the time of the Black Death that would have seriously reduced the stock of plow and work animals. In addition to the general decline in population, there was a migration of people from the country to the cities, for studies show a substantial reduction in the number of villages in Egypt.<sup>68</sup> This movement was spurred by the privations in the countryside, by a search for medical attention during time of plague, and by the attraction of high wages paid in the cities because of the general shortage of labor. Following the Black Death, the price of goods that required a substantial labor force to manufacture greatly increased. Sugar was no exception.<sup>69</sup> Beset by war and plague, during the fourteenth and fifteenth centuries Egypt ceased to be an important source of sugar.

The repercussions of plague and warfare rather than technological stagnation and Mamluk misrule led to the decline of sugar production in the Levant, but lands farther west also suffered from war and plague. In the western Mediterranean encouragement of and investment in the sugar industry overcame the loss of labor. The decline of such major producers as Egypt and Palestine left a gap in the sugar trade which other states endeavored to fill. Venice and Genoa, deprived of their lands in the Levant, actively supported the development of the industry elsewhere in the Mediterranean. The Cypriot and Cretan industries expanded in the fourteenth century and flourished in the fifteenth. The purchase of slaves is only one example of investment in the industry. An increase in production in Granada, where the Genoese played an important role in the trade, converted this last Moorish kingdom on the Iberian Peninsula into a virtual colonial territory. The Genoese also attempted to establish sugar cultivation in the Algarve and became heavily involved in the industry in the Canaries and Madeira.<sup>70</sup> In Italy, there is evidence of a redirection of capital investment from commerce to agriculture.<sup>71</sup> The expansion of the western Mediterranean industry continued throughout this period even though sugar had begun to arrive from Madeira and the Canaries. This increase in the supply led to a fall in the

<sup>66</sup> This historiography has been reviewed by Udovitch (*ibid.*, pp. 117-118). Ashtor (Levantine Sugar Industry [see footnote 34 above] and *Histoire des Prix* [see footnote 63 above]) follows this interpretation. For the economic problems of Egypt under the Sultan Barsbay see Ahmad Darrag: *L'Égypte Sous le Règne de Barsbay, 825-841/1422-1438* (Institut Français de Damas, Damas, 1961).

<sup>66</sup> Udovitch, *op. cit.* [see footnote 64 above], pp. 118-120; and Michael W. Dols: *The Black Death in the Middle East* (Princeton Univ. Press, Princeton, N.J., forthcoming). I am extremely grateful to Professor Dols for permitting me to read the manuscript.

<sup>67</sup> In this paragraph I have relied on Dols, *op. cit.* [see footnote 66 above].

<sup>68</sup> Udovitch, *op. cit.* [see footnote 64 above], p. 115.

<sup>69</sup> See Ashtor, *Histoire des Prix* [see footnote 63 above], esp. p. 460.

<sup>70</sup> Jacques Heers: *Le Royaume de Grenade et la politique marchande de Gênes en Occident (XV<sup>e</sup> siècle)*, *Le Moyen Âge*, Vol. 63, 1957, pp. 87-121, esp. pp. 109-111 and 113; and Heers, *Genes au XV<sup>e</sup> Siècle* [see footnote 61 above], esp. pp. 485-496.

<sup>71</sup> Robert Lopez: *Italy, part of Lopez, Miskimin, and Udovitch, op. cit.* [see footnote 64 above], pp. 107-115, reference on pp. 107-108; and Jones, *op. cit.* [see footnote 15 above], p. 370.

price of sugar,<sup>72</sup> but the new producers did not replace the old, for in the growing economy of the "long sixteenth century"<sup>73</sup> Europe was able to absorb the sugar from the Atlantic colonies and from the Mediterranean.

The end of the sugar industry in Cyprus, Crete, and the western Mediterranean came in the brief period of thirty years, approximately 1570 to 1600. In Cyprus, sugar was an important crop during the 1560's, but by 1600 the industry had collapsed, and sugar crops were replaced by cotton. Sugar ceased to be an important crop in Sicily in the last years of the sixteenth century.<sup>74</sup> By the end of the century, the Granadan industry had been reduced to seven mills and a few acres of cane in the vega of Motril.<sup>75</sup> In Morocco, the decline of the sugar industry coincided with a period of civil strife, which was reported by traders in 1576. In 1603, there were further reports of damage to mills, but no indication was given of the amount of sugar still being produced. Finally, in 1622 Antony Sherley, an English merchant in Granada, reported that the Moroccan industry no longer existed.<sup>76</sup> By 1600, sugar had ceased to be a major cash crop in the Mediterranean. However, sugarcane continued as a garden curiosity in Valencia and Sicily into the eighteenth century and survived as a minor cash crop along the southern coast of Spain.

The collapse of the Mediterranean industry was caused by the arrival in Europe of Brazilian sugar at a price below that at which sugar could profitably be produced in Mediterranean industries. In 1580, Brazil and Portugal came under Spanish control; therefore, Brazilian sugar entered Spanish dominions, and it undersold Sicilian sugar even in Palermo.<sup>77</sup> Brazilian sugar was handicapped by high transportation costs but enjoyed environmental advantages. Sugarcane could grow to maturity and yield more sugar in Brazil than around the Mediterranean. It was cultivated without the expense of irrigation and there was an abundance of fuel and land. Around the Mediterranean, land, especially irrigated land, was scarce and valuable, and sugar had to compete for space with other crops. Imports of inexpensive Brazilian sugar increased, and the time came in the late sixteenth century when other Mediterranean crops were more profitable than sugar.

In addition to competition from Brazil, other explanations for the decline of the industry are the expulsion of the Moriscos from Spain, deforestation, and climatic change.<sup>78</sup> After the conquest of Granada, some of the Morisco population was dispersed to other parts of Spain and eventually, between 1609 and 1614, many Moriscos, who were skilled workers, were expelled from the country. The significance of the expulsion may have been exaggerated because research has shown that it was not as complete nor the economic consequences for Spain as grave as was once thought. Moreover, many of those expelled from Spain came from Valencia, which

<sup>72</sup> For the decline in price, see G. B. Masfield: *Crops and Livestock*, in *The Cambridge Economic History of Europe* (edited by E. E. Rich and C. H. Wilson; Cambridge Univ. Press, Cambridge, 1967), Vol. 4, pp. 276-301, reference on p. 287; and Heers, *Royaume de Grenade* [see footnote 70 above], p. 113.

<sup>73</sup> The phrase is Braudel's (*op. cit.* [see footnote 1 above], Vol. 2, pp. 892-900).

<sup>74</sup> Hill, *op. cit.* [see footnote 59 above], p. 817; Trasselli, *op. cit.* [see footnote 43 above], p. 146; and Masfield, *op. cit.* [see footnote 72 above], p. 290.

<sup>75</sup> Blume, *op. cit.* [see footnote 27 above], pp. 98-99.

<sup>76</sup> Berthier, *Sucreries du Maroc* [see footnote 5 above], pp. 269-272.

<sup>77</sup> Trasselli, *op. cit.* [see footnote 43 above], p. 146.

<sup>78</sup> For the Moriscos see Blume, *op. cit.* [see footnote 27 above], p. 98; and Masfield, *op. cit.* [see footnote 72 above], p. 290. Berthier (*Sucreries du Maroc* [see footnote 5 above], p. 277) considers that environmental changes militated against the restoration of the Moroccan sugar industry, and Denis Mack Smith (*Medieval Sicily, 800-1713* [Chatto and Windus Ltd., London, 1968], pp. 183-186) suggests that climatic change adversely affected sugar production in Sicily.

was not a major center of sugar production.<sup>79</sup> Deforestation added gradually to the difficulties of the industry. The progressive destruction of the Mediterranean forests not only made fuel increasingly scarce and presumably more expensive but also caused soil erosion in the hills and silting in the plains, which further complicated the maintenance of irrigation. No evidence exists that the fuel supply dramatically worsened in the second half of the sixteenth century.

The rise and fall of the Mediterranean sugar industry has also been linked to climatic change because of the rough coincidence between its establishment in a notably warm period, which reached a peak about 1000–1200, and its decline in the western areas with the onset of the so-called Little Ice Age of approximately 1550–1700. During the warm or optimum period, temperatures were about 1–2°C above present values to the north of 40°N and rather less to the south. In the south, during the warm period there was probably more rainfall than at present.<sup>80</sup> It is difficult to assess the impact of such minor changes on sugar cultivation. Presumably the risk of frost damage during the Mediterranean winter did not disappear during the warm period, though it must have been less in the climatic optimum than in the later cooler period. Le Roy Ladurie, using examples from northern Europe, recently cautioned against accepting climatic rather than economic explanations for agricultural change.<sup>81</sup> To accept climatic fluctuations as the significant force in the rise and decline of the Mediterranean sugar industry decreases the roles of economics and major historical events. Moreover, the rapid collapse of the Mediterranean sugar industry, in a thirty-year period, suggests that neither climatic change nor deforestation was a major cause. These are gradual processes that take effect over many decades, if not centuries. Competition from American sugar suppliers is a more likely explanation of the sudden decline.

The first phase of the Mediterranean sugar industry was marked by experimentation. After the Arab agricultural revolution agricultural techniques changed little, if at all, and even milling remained largely unchanged with the continuing use of technology dating from classical times. Waterpower was the only major innovation in milling, although it did not supplant other forms of power. During the later years of the industry, change was most obvious in the organization of trade, labor, and land. Gradually the characteristics of the colonial plantation system emerged. Aspects of the system were discernible even in the Crusader states and became more noticeable in the development of the sugar industry in Crete and Cyprus. The settlement of Madeira, the Azores, the Canaries, and São Tomé marked further stages in the development of the new system, so that by the early sixteenth century, when the settlement of Brazil began, the plantation system was already a tested form of colonial land use. In the Americas, with an abundance of land, an ideal climate, and a supply of slave labor, sugar production found scope to flourish.

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<sup>79</sup> Henri Lapeyre: *Géographie de L'Espagne Morisque* (S.E.V.P.E.N., Paris, 1959); and Braudel, *op. cit.* [see footnote 1 above], Vol. 2, pp. 792–797.

<sup>80</sup> I have followed here H. H. Lamb: *The Early Medieval Warm Epoch and Its Sequel*, *Palaeogeography, Palaeoclimatology, Palaeoecology*, Vol. 1, 1965, pp. 13–37.

<sup>81</sup> Le Roy Ladurie: *Times of Feast, Times of Famine: A History of Climate Since the Year 1000* (Doubleday and Company, Inc., Garden City, N.Y., 1971).