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The Arab Agricultural Revolution and Its Diffusion, 700-1100

THE rapid spread of Islam into three continents in the seventh and eighth centuries was followed by the diffusion of an equally remarkable but less well documented agricultural revolution. Originating mainly in India, where heat, moisture and available crops all favored its development and where it had been practiced for some centuries before the rise of Islam, the new agriculture was carried by the Arabs or those they conquered into lands which, because they were colder and drier, were much less hospitable to it and where it could be introduced only with difficulty. It appeared first in the eastern reaches of the early-Islamic world—in parts of Persia, Mesopotamia and perhaps Arabia Felix—which had close contacts with India and where a few components of the revolution were already in place in the century before the rise of Islam. By the end of the eleventh century it had been transmitted across the length and breadth of the Islamic world and had altered, often radically, the economies of many regions: Transoxania, Persia, Mesopotamia, the Levant, Egypt, the Maghrib, Spain, Sicily, the savannah lands on either side of the Sahara, parts of West Africa and the coastlands of East Africa. It had very far-reaching consequences, affecting not only agricultural production and incomes but also population levels, urban growth, the distribution of the labor force, linked industries, cooking and diet, clothing, and other spheres of life too numerous and too elusive to be investigated here.

This paper will first describe the main features of the Arab agricultural revolution and then try to explain its diffusion.

In the course of my research, which has been carried on over a number of years and in many places, I have benefited from innumerable kindnesses, great and small, which will be acknowledged elsewhere. Here I should like to thank those to whom my debt is especially large: Professors Claude Cahen, Pedro Martínez Montávez, Roland Portères, Vivi Täckholm and John Williams, and Drs. David Dixon, Hans Helbaek, Jean-Jacques Hémardinquer and Carmello Trasselli. I am also grateful to Professors C. A. Ashley and Karl Helleiner and Dr. Roger Owen for commenting on drafts of this article. As this article is a preliminary report on my research, the very numerous primary and secondary sources used have not been cited. The reader who is interested in the primary sources will find some guidance in the Appendix. In my forthcoming book, *New Crops in the Early-Islamic World: A Study in Diffusion*, most of the points made in this article are developed in greater detail and full references are given.

I

At the very heart of the revolution were many new crops. Found by the Arabs mainly in India, and in a few cases in the lands of the conquered Sassanian Empire, which had received them from India, the new crops were introduced into other, very different climatic regions where they played an important part in transforming cropping patterns. To mention only those plants whose progress we have been able to study in detail—sixteen food crops and one fibre crop—the Arab conquests were followed by the diffusion of rice, sorghum, hard wheat, sugar cane, cotton, watermelons, eggplants, spinach, artichokes, colocasia, sour oranges, lemons, limes, bananas, plantains, mangos and coconut palms.¹ With the exception of mangos and coconut palms, which could be grown only in tropical climates and therefore appeared only in Arabia Felix and along the coast of East Africa, the diffusion was very wide: the new crops came to be grown in nearly the whole of the early-Islamic world and not a few became, for smaller or larger regions, of great economic importance.

This list of new crops is already long and impressive, but it is far from complete. It does not include other food and fibre crops diffused in the same period, whose advance has proved difficult to trace in the sources. Nor does it include plants known in these regions before the Arab conquests, new strains of which appeared and were diffused in Islamic times. It excludes plants and trees used principally as sources of fodder, spices, condiments, medicines, drugs, cosmetics, perfumes, dyes, nuts and wood, as well as garden flowers and ornamental plants. In the dissemination of all these kinds of crops, too, the early centuries of Islam saw great progress. And finally, the list omits a whole host of unwanted weeds which were inadvertently diffused along with the other plants, some of which were later to prove valuable but about whose inglorious history almost nothing is known. In short, a complete list of even only the useful plants would be long indeed, numbering well into the hundreds. The achievement was remarkable. It seems all the more so when we remember that the diffusion of these plants over a very large area was compressed into the first four centuries of Islam; that most of the plants, being native to tropical regions, were not

¹ Separate chapters will be devoted to the study of the diffusion of each of these crops in pre-Islamic and Islamic times in my forthcoming book mentioned in the preceding footnote.

easy to grow in the cooler and drier regions into which they were taken; that the plants had revolutionary effects on the whole agricultural system; and that the work of introducing and spreading these crops was done by—or at least under the rule of—a people not commonly thought to have green thumbs. There had been little that was comparable in earlier history. The achievement was not to be equalled until modern times, when the discovery of new continents allowed the exchange of plant life between parts of the world which had previously had little or no contact.

Hand in hand with the new crops came changes in farming practices. For one thing, a number of the new crops led to the opening of a virtually new agricultural season. In the lands of the Middle East and Mediterranean the traditional growing season had always been winter, the crops being sown around the time of the autumn rains and harvested in the spring; in the summer the land almost always lay fallow, usually even in irrigated regions where at least some of the crops available to the ancients could, with special care, have given satisfactory yields. Those crops mentioned as summer crops in the classical Roman manuals—barley, *trimestre* wheat, sesame and various legumes—played a minor role in some parts of the *northern* Mediterranean, where the summer was relatively cool, though even there they seem to have been little used and were not integrated into any systematic rotation. But in the southern and eastern parts of the Mediterranean they were practically never grown, at least not as summer crops. There the summer season was to all intents and purposes dead. Since, however, many of the new crops originated in tropical regions of India, Southeast Asia, and Central Africa, they could be grown only in conditions of great heat. In particular, rice, cotton, sugar cane, eggplants, watermelons, hard wheat and sorghum were all summer crops in the Islamic world, though rice and hard wheat could also be winter crops in certain very warm areas. Several other important new crops which we have not been able to study in detail, such as indigo and henna, were also grown in summer. Through the introduction of summer crops on a wide scale, therefore, the rhythm of the agricultural year was radically altered as land and labor which had previously lain idle were made productive.

More than this, the opening of a summer season was one of several factors—perhaps the principal one—permitting systems of rotation which made much more intensive use of the land. Whereas in

Roman, Byzantine and Jewish agricultural traditions, the normal practice was to crop the ground only once every two years, and under very exceptional circumstances once every year, there appeared all over the Islamic world rotations in which the land was cropped four times or more, instead of once, in a twenty-four month period. Thus winter wheat could be followed by summer sorghum. As one traveler observed in Cyprus, where the practice had no doubt been introduced during the Arab occupation, a summer crop of cotton could be just fitted in between two crops of winter wheat grown in successive years. In parts of the Yemen wheat yielded two harvests a year on the same land, as did rice in Iraq. Where plants with a shorter growing season were used, such as spinach, colocasia or eggplants, the land could be cropped three or more times a year. The variations were endless. Naturally, multiple cropping mined the fertility of the land and could not be borne by every type of soil. But to combat exhaustion and even to improve some soils, the Arab manuals recommended extensive use of all kinds of animal and green manures, each with its special qualities and uses, as well as ashes, rags, marl, chalk and crushed bricks or tiles. They also urged much plowing, digging, hoeing and harrowing which, they stated, were to some extent substitutes for fertilizing and on occasion preferable: according to al-Maqrīzī land in Egypt was plowed six times before sugar was planted, while Ibn Baṣṣāl recommended up to ten plowings—and manuring—before cotton was sown.

The new cropping pattern required much water, which in the lands of early Islam could be provided only by artificial irrigation. In part, extra water was required simply because the land was cropped more or less continuously and therefore could not regain moisture during the long periods of fallowing which had characterized earlier agriculture. In part, too, water requirements were greater because the summer crops were grown at a time when—except in Arabia Felix—no rain fell. The new summer crops, mostly native to tropical lands, were particularly demanding of water. Sugar, for instance, when grown along the Nile, required not only the river's annual flooding—or the equivalent amount of water artificially brought to the land—but also twenty-eight heavy waterings after that; in Spain sugar was watered every four to eight days. Rice, according to Ibn Waḥshīya, had to be grown on level land which was continuously covered with water from planting to harvest, though Ibn Luyūn said that it could be grown if watered twice before the seed germi-

nated and twice weekly thereafter. Similarly, many of the other crops required heavy waterings through much of their growing season. Even those of the new crops which usually did not *require* artificial watering—sorghum, hard wheat, watermelons and egg-plants, for instance—gave much higher yields if watered at the right times. So, too, did the crops of traditional agriculture.

But although many of the lands overrun by the Arabs (and parts of the Arabian peninsula itself) had known extensive irrigation systems in pre-Islamic times, the irrigation works to which the Arabs fell heir needed much improvement before the new agriculture could be introduced. One difficulty was that by the middle of the seventh century many of the ancient systems had fallen into decay. In Mesopotamia, for instance, the neglect of irrigation in the last half century of Sassanian rule culminated in a huge flood in the year 629, which destroyed many embankments and works, including the great Nimrud dam, and left the lower reaches of the Tigris a marshy quagmire. In Arabia Felix, another large dam, that of Ma'rib, broke in the later part of the sixth century, after which there is no evidence that *any* Himyaritic irrigation works were in operation. In late-Roman North Africa and Byzantine Egypt, too, the area under irrigation shrank in the centuries before the rise of Islam. And while we have no knowledge of the fate of the irrigation works of Spain during the rule of the Visigoths, one of the Arab conquerors of Iberia was reported to say—wrongly, surely—that there was not a single canal in the country. A second problem was that the irrigation technology of the pre-Islamic world was by and large inadequate for the new agriculture. With the exception of the Mesopotamian system, pre-Islamic irrigation consisted almost entirely in the temporary trapping of rain water or river floods and the spreading of them by gravity flow over the land. It therefore brought water mainly in one season, the time of rains or floods, and could reach only those lands to which gravity flow could be directed. Though efficient devices to overcome these shortcomings existed in the pre-Islamic world, they were in only limited use. With this legacy of irrigation systems and technology, therefore, the new agriculture could make little progress across the world the Arabs had conquered. Advances were easiest in parts of Persia and Upper Mesopotamia, where elements of a more sophisticated system were already in place. Elsewhere they had to wait upon progress in irrigation.

This soon came. Although deterioration may have continued during the early years of Islam while conquest proceeded and power was slowly consolidated, the period from the early eighth century onwards saw a sharp reversal. Old irrigation systems were almost everywhere repaired and often extended. New ones were built. At the same time, the range of technology from which irrigators could choose was greatly widened by the spread through the Islamic world of a profusion of devices, borrowed rather than invented by the Arabs, for catching, storing, channeling and lifting water. Among the more important of these were new kinds of dams, underground canals (or *qanāt*) which tapped ground water and brought it over long distances, and a variety of wheels turned by animal or water power and used for lifting water—sometimes to great heights—out of rivers, canals, wells and storage basins. The result was to bring much more water to much more land: to irrigate lands which in earlier systems were not, and often could not have been reached, and to improve the *quality* of irrigation, that is to increase the flow of water on many lands watered by more primitive techniques in earlier times. So great indeed was the progress made that it would be only a slight exaggeration to claim that by the eleventh century there was hardly a river, stream, oasis, spring, known aquifer or predictable flood that went unused. Many were fully or almost fully exploited, though not always by irrigators, who had to compete with other users. The combined effect of all these advances was to create across the Islamic world a patchwork of heavily irrigated areas, great and small, into which the new agriculture could move, to transform an environment fundamentally hostile to many of the new crops into one in which, for a time at least, they were grown with astonishing success.

But the agricultural revolution was by no means confined to heavily irrigated and fertile areas where multiple cropping on the Indian model could be introduced. On the contrary, though the impact of the revolution was greatest in such areas and though they may perhaps be regarded as the spearheads of agricultural advance, the new agriculture overflowed their bounds to affect the whole spectrum of land types—from best to worst—that the early-Islamic peasant tilled. Virtually all categories of land came to be farmed more intensively. In part, this spillover was made possible by the fact that there was no sharp break between irrigated and unirrigated lands. Rather the various advances in irrigation had endowed

the early-Islamic world with a gradation of artificially watered lands: at one end of it were those which were under heavy, perennial irrigation and could support the Indian system of cropping; in the middle was a wide range of lands watered less heavily through the year or for only parts of the year; and at the opposite end were lands watered only one or twice in a season through the capture, for instance, of a flash flood or through sparing use of small amounts of water stored in a cistern. The possibilities which partial irrigation opened up for intensifying land use were compounded by the fact that the authors of the Arab farming manuals identified far more types of soils than are mentioned by the ancients. By taking into account structure, temperature and moisture of the soil, they were able to see much more clearly than their predecessors the potential of each soil type. They assumed that *all* soils would be used to their full capacity—even inferior and downright bad lands, which the ancient writers did not deign to consider.

Furthermore, in devising cropping patterns for lands on which the most intensive agriculture could not be introduced, early-Islamic landowners and peasants could choose from a much wider range of crops, the special requirements of which they understood better than their predecessors. There were all the crops of traditional agriculture, the many new crops which were being diffused, and new *strains* of old and new crops which, from the accounts of many writers, seem to have abounded. With this wider choice available they were able to invent an almost infinite variety of flexible rotations which contrast sharply with the small number of rigid rotations of antiquity. These could involve the elimination of fallowing in alternate years, an irrigated winter crop followed by an unirrigated summer crop or vice versa, the insertion of catch crops (such as turnips, all kinds of legumes, and small fruits and vegetables) between the major crops, and the varying of crops over a period of years so that six or eight different crops might follow in succession on the same land, each chosen in the light of what had preceded and what was to come next. By ingenious combinations which took full account of the degree of watering available and the type of soil, they were able to crop almost all categories of land more heavily than in the past, and sometimes to achieve particularly spectacular results by taking advantage of local soil variations and microclimates.²

² For several of the ideas developed in this paragraph and the preceding one, I

Even on lands which in earlier times had been thought too dry, too hot, or too infertile to use, and which no artificial watering could reach, the new agriculture made important advances. Here again certain of the new crops were crucial. Though it required some moisture in the early part of its growing season, sorghum, for instance, could mature in a summer that was very hot and dry; it could also, as the Arab manuals pointed out, be grown on hard and sandy soils which other crops would find inhospitable, and could even help to reconstitute these lands. Hard wheat could also endure much heat and drought. Though of less importance, watermelons, too, yielded satisfactory returns on lands once thought too dry to use. These crops thus allowed the margin of cultivation to be pushed back into the savannah or near-desert lands in which the Islamic world abounded—lands which previously had been used only for sporadic grazing or had gone unused. Similarly, sugar cane, colocasia, coconut palms and eggplants could be grown on salty soils, upon which cereals could not be grown, and helped to improve these. They therefore encouraged an extension of cultivation into swamp lands lying along seacoasts and at the mouths of rivers, into lands watered by slightly brackish springs, and into lands which after centuries of irrigation had become too saline for other crops. Again, we learn from Ibn al-‘Awwām that cotton was grown on the *worst* lands of Spain and Sicily, and we may assume that this crop also helped to push back the frontiers of sedentary agriculture.

One of the direct consequences of the new agriculture was higher and more stable agricultural earnings. The total income generated by the agricultural sector was higher because more land was farmed, because more cultivated land was irrigated, because land was cropped more intensively, and because there was a wider variety of crops to choose from—some much more profitable than anything available in earlier times. But the new agriculture also helped to stabilize agricultural incomes. No longer was the rural community so dependent on a single harvest, the size of which was at the mercy of an undependable climate. Instead an increasing number of producers could rely on two or more crops which matured at different times of the year and whose exact time of maturation, in the case of irrigated crops, could to some extent be controlled by regulating the flow of water. Moreover, with more land under irrigation, the damage inflicted by climatic fluctuations was greatly reduced, since

the flow of streams and the output of wells varied much less than rainfall; on this account, too, the level of output—and hence earnings—varied less. The fact that hard wheat and sorghum could be stored over very long periods allowed speculators and governments to build up surpluses in years of high production and low prices which could be released onto the market in years when production was low and prices high. Because such activities tended to keep supplies of grain on the market more nearly stable, they also helped to stabilize prices and incomes, though occasionally the tactics of unscrupulous speculators and governments had the opposite effect. More stable incomes were important not only in alleviating the periodic misery which punctuated the lives of rural dwellers in earlier agricultural systems; they also made it easier for peasants to meet their obligations to landowners and to the State, and thereby helped for a time to keep intact a relatively prosperous and free peasantry and to prevent the excessive buildup of large estates.

Both capital and labor costs, however, were higher per land unit. More capital was required for the construction of irrigation works and for the leveling or terracing of land to be irrigated. In a less obvious but perhaps important way, the new agriculture probably also demanded a higher investment in tools, draft animals and out-buildings. Operating capital was also greater on account of the larger amounts of seed, fertilizer and labor used on a given land area in the course of a year. But this increase in capital did not on balance displace labor. On the contrary, though greater investment allowed certain activities to be performed with less labor, many operations were added which had not been carried out in earlier agricultural systems and the result was to increase, not reduce, labor requirements per land unit. In fact, the new agriculture was extremely labor-intensive. More labor was required to construct, repair and operate the irrigation works; to plant, care for and harvest crops on land that was more frequently cropped; to tend to certain of the new crops, such as sugar, which made much higher demands on labor than any of the crops of traditional agriculture; and to carry out the enormous amount of plowing, digging, hoeing and harrowing, as well as the extensive fertilizing, which were needed to maintain the fertility of heavily cropped land. While some of the tasks of the new agriculture came in what had been the dead or slack seasons of earlier systems, and could therefore be performed by labor that would otherwise have lain idle, more hands were undoubtedly needed per land unit. This growing labor-intensiveness

of agriculture, combined with the expansion of the total area under cultivation, created the need for a much larger agricultural labor force.

Higher incomes per land unit, the availability of new land and the greater demands of the new agriculture for labor probably all encouraged early marriage and large families and thus may have caused rural populations to grow. In any case, whatever the explanation, there are signs from many parts of the early-Islamic world that the countryside was becoming more densely settled. Although no evidence has survived which allows us to document this phenomenon in detail, we find that in many areas villages seem to have been larger and more numerous and that they extended into regions which in earlier (and often later) times were not farmed. To give only a few examples, some of which surely contain an element of exaggeration, chroniclers or geographers tell that there were 360 villages in the Fayyum, each of which could provision the whole of Egypt for a day; that there were 12,000 villages along the Guadalquivir, which, if this was true, must have had little agricultural land; that the coast between Tangiers and Melilla, which today is almost entirely abandoned, was densely settled and prosperous; that on the road between Gafsa and Feriana, a part of Tunisia which today is desert, there were 200 villages; and that along the Tigris settlement was continuous, so that before dawn crowing cocks answered one another from housetop to housetop all the way from Baghdad to Basra. Other kinds of evidence support the same thesis with slightly greater precision: an eighth-century census of 10,000 villages in Egypt showed that no village had fewer than 500 plows, while data from the seigneurie of Monreale in Sicily suggest that some hundred years after the Norman conquest of the island—by which time depopulation may already have set in—the rural areas of the seigneurie, amounting to some 1,000 square kilometers, had about 20,000 inhabitants. If in a few areas, such as the Negev and the region of the *villes mortes* near Aleppo, settlement actually retreated, and in other areas, such as the Diyala Plains, the evidence of growth is not clear, the overwhelming weight of evidence is on the side of heavy growth of rural population. Almost everywhere frontiers were pushed back, empty spaces filled up, and settlement became denser and more continuous—all changes of great significance not only for agriculture but also for the development of trade, communications and central administration.

Cities were also growing: proof that, in spite of denser rural pop-

ulation, the countryside could export an increasing surplus of food-stuffs. Here again our information is fragmentary and usually unsatisfactory, but its combined weight supports the thesis of impressive urban growth. To be sure, some coastal cities, such as Alexandria, Antioch and Carthage, declined as a more continental economy with an eastern orientation appeared on the African and Levantine shores of the Mediterranean. But the old inland cities, such as Cordoba, Seville, Damascus and Aleppo, flourished perhaps as never before, and hundreds of virtually new cities, mostly inland, were founded in almost every part of the early-Islamic world. Many became of great economic importance. By contemporary European standards, not a few were enormous. Samarra, for instance, which was the capital of the Eastern Caliphate for only a short time, was estimated by Herzfeld, who excavated it, to have had a population of about a million in 883; Baghdad was certainly larger than Samarra. Cordoba, whose population in the tenth century Lévi-Provencal conservatively estimated at 500,000, is now claimed by archeologists to have contained about a million people. Although we cannot estimate the population of Fatimid Cairo, nor any of the earlier foundations out of which Cairo had grown, its great area and the apparently high density of population in parts of it speak for a very large city; so, too, do many indications (of varying reliability) in the texts which tell of 100,000 houses in the quarter of al-Qaṭā'ī alone, of 400,000 soldiers who were billeted in the city in the tenth century, of 50,000 donkeys to transport wares to and from the markets in the quarter of al-Fuṣṭāṭ, and so forth. Other great cities there certainly were, and a host of medium-sized and smaller towns. All stood as witness to the agricultural advances of this world which was becoming more populous and, quite possibly, more urbanized.

II

Let us turn now from the facts of this agricultural revolution and its diffusion—which have been difficult enough to establish—to the still more difficult questions of how and why this diffusion occurred. What particular conjuncture of factors favored the rapid transmission of new crops, farming techniques and irrigation technology at this particular point in time? Why did this revolution not occur earlier, or later? Why did it occur at all?

Questions of this kind are not easy to answer. To explain is usu-

ally more difficult—and more risky—than to describe. But in this particular case the nature of the data available makes such an undertaking especially perilous. The sources, which tell us much about the revolution itself, say nothing about the agents of its transmission. Were they royal personages, many of whom were known to take an interest in farming and botany, and to have collected exotic plants in botanical gardens? Were they great landowners, who saw the commercial possibilities that agricultural innovation opened up? Or were the unsung heroes simple peasants who in the course of migrating westward brought with them the crops and farming techniques that they had known in the East? We cannot know, though we may suppose that all three groups were involved. Nor do the sources help us much to get a picture of the structure and organization of the agricultural world into which these changes were received. The kind of documentation which abounds for many countries of medieval Europe—namely, the records of landed estates—has failed to survive from the early-Islamic world. We therefore do not know what the typical (or indeed *any*) agricultural undertaking was like, and cannot be sure what features of agrarian organization particularly favored the diffusion of the agricultural revolution.

Nevertheless, from the available sources we can catch glimpses of a wide variety of factors which seem to have facilitated the spread of the revolution. So many are these, and so diverse, that here we can touch on only a few and must do so with utmost brevity.

A Medium of Diffusion

To begin with, we shall argue that the early-Islamic world brought into being a medium which was peculiarly receptive to many kinds of novelty and favored their transmission. Many areas of life were affected by its properties of conduction, of which agriculture was only one. The creation of this medium began with the Muslim conquests, which led to the uniting of a large part of the known world under one language, one religion, one legal system, and for a time one rule. Many of the regions brought together had never before been in direct contact; certainly the extremities of the Islamic world in 1000 had never before enjoyed such prolonged contact with one another. The area united was diversified as well as large, including a wide range of climatic zones and plant life of

very great variety. It was also strategically located, with footholds on three continents; by reaching beyond the frontiers of Islam still farther into these continents, the early Muslims were able to make contact with all the other areas of the known world—areas which offered, among other things, a still greater variety of plant life. In fact, partly because of their strategic location, throughout the European Middle Ages the Arabs were the only people with what might be considered a reasonable knowledge of all three continents of the known world.

Within the area of Arab dominion, and to some extent beyond, there was much movement of men, of goods, of technology, of information and of ideas. Ibn Khaldūn wrote of the Arabs that “all their customary activities lead to travel and movement,” and so it was to become not only of the Arabs themselves, or those of Arabic stock, but also of the conquered peoples. The very process of conquest and settlement of new areas often led to considerable movements of peoples. Basra, for instance, and some of the new cities founded in the south of Iraq, show a strange amalgam of peoples: Yemenites, other Arabs, Persians, and Indians all settled there, and one may suppose brought with them the techniques of farming and the crops known in their homelands. Muslim Spain was settled by Berbers from North Africa, as well as by immigrants from Egypt, the Yemen, Syria and still farther East. Trade, which it seems began to flourish soon after the Islamic conquests, gave rise to still further movement, a movement which linked together all areas of the Islamic world and even areas lying beyond the outer reaches of Islam. The pilgrimages which Muslims made in great numbers, and particularly the pilgrimage to Mecca, brought together Muslims from distant corners of the earth. Many pilgrims took advantage of their displacement to prolong their stay abroad, making visits to relatives in other countries, studying in foreign centers of learning, and just sightseeing. Political refugees, of whom as time went on there was an increasing number, account for still more movement. To these should be added men of religion and scholars, both of whom traveled widely; the authors of Arab manuals of farming, books on botany and pharmacopoeiae almost all traveled extensively, many the length and breadth of the Islamic world. But perhaps any attempt to explain why people traveled in the Muslim world is doomed to fail to account for the really extraordinary amount of coming and going across huge stretches of land which we find all

through the Islamic sources from the period. All classes of people, it seems, were prone to this restlessness; all traveled—the rich and the poor, the scholar and the illiterate, the holy and the not so holy. Poverty was no obstacle: one could move by foot, begging along the way; relatives could be imposed upon endlessly; patrons were readily found for scholars or holy men, or those who posed as such; a place to bunk, and perhaps to eat, was available outside the main mosque in most cities. Lured on in search of money, adventure or truth, Muslims from every region left home and roamed to and fro over the continents, taking with them knowledge of the farming techniques, plant life and cookery of their homeland, and seeing on their way the agricultural practices, plants and foods of new lands.

In their travels the Muslims of the early centuries of Islam were on the lookout for whatever could be learned. This was an attitude of mind that went back to earliest days of Islam. Perhaps because the Arabs came out of an area which was a cultural, and sometimes an actual desert, and overran areas of high and ancient civilization, they were from the beginning aware of their intellectual and material deficiencies, immensely receptive to the new, eager to learn from those who could teach, avid to ape the fashions of the great centers. Into the task of assimilating the material and intellectual culture of the ages they threw themselves with all the enthusiasm of the *nouveau riche*. At the court of the early Abbasid Caliphs in Baghdad, for instance, manuscripts from all over the world were collected, and as these could be read only by scholars, the translation of books from Greek, Persian, Syriac and Sanskrit was actively promoted for over a century. Among the books so translated were many works on agriculture, botany and pharmacology, all of which helped to make Arabs familiar with plants they had not seen. Much labor was spent in identifying these plants, and some of the early lexicographical works are devoted solely or partly to this problem. Similarly, in Spain, the Far West of the Eastern world, and during the early centuries of Islamic rule a backwater, the buying of culture was pursued with a vengeance. There the Umayyad rulers spared no effort in attracting scholars from centers of learning and building up libraries. Although almost all of the Spanish Umayyad rulers were active in bringing culture to their people, the work of al-Mustansir was perhaps exceptional: he sent agents to Baghdad, Damascus, Cairo and other centers to purchase whatever valuable books could be found. The Imperial Library contained, according

to one source, 400,000 volumes. The listing of these books filled 44 index catalogues of 20 folios each. The latest books were said to be available in the Library almost before anyone had read the books in the East. Translators, copiers, bookbinders were legion.

As far as material culture was concerned, the Arabs in their travels showed the same eagerness to reach out and acquire whatever was to be had from the far corners of the earth, and Arabs became perhaps the greatest collectors of all times, building up huge collections of rare and exotic objects. Not only rulers and their courts, but other prosperous people set about collecting in the grand manner whatever took their fancy, or whatever they thought might impress: rare birds, wild animals, beautiful slaves, jewels, coins, plates, rugs, plants and, as we have seen, books—all from all over the world. An unkind soul might go on to point out that the books themselves were in many cases little more than collections—collections of foreign or obsolete words, of odd facts, of names of plants, medicines or places, or of sayings, writings and judgments, and so on—with little in the way of theory or interpretation. The modern reader may find such books indigestible but they delighted the mind that sought to possess, enjoy and doubtless to show off all the good things the world had to offer.

In the medium which was being thus created in the world of early Islam there were many directions of flow, for in this essentially syncretic civilization whatever could be usefully assimilated was snapped up and diffused. But one channel was of overriding importance: it began at the eastern extremity of the Caliphate, in India and Persia, and traversed the entire breadth of the Islamic world up to Morocco and Spain. The eastern provinces early became the gateway for the entry of Indian and Persian culture which was eagerly sought after there and farther to the West. This movement westwards was intensified with the rise of the Abbasid dynasty at Baghdad in the middle of the eighth century; these rulers and their courts consciously imitated Indian and Persian customs, and they in turn were imitated by a whole series of courts which sprang up farther to the West—in Egypt, Tunisia, Morocco and Spain. Over this east-west route moved not only most of the new crops, the farming practices and the irrigation technology that were the main components of the agricultural revolution, but much else that was to shape the world of classical Islam: higher learning, industrial technology, fashions of dress, art forms, architecture, music, dance,

culinary arts, etiquette, games and so forth. The end result of so much diffusion through this medium was at once to strengthen the unity, begun by the conquests, of this vast world and to set it apart from both its predecessors and its neighbors. There emerged a civilization with a look of newness fashioned out of elements that, for the most part, were old.

The Pull of Demand

But a medium of diffusion, however great its receptivity and its powers of conduction, was not enough. For the new crops, and with them the agricultural revolution, to be disseminated on a wide scale and to become of great economic importance, much more was needed. On the one hand, there had to be a substantial demand for the new crops as foodstuffs or, in the case of cotton, as a textile fibre—a demand which had to be created since the crops were new. And on the other hand, producers had to be able and willing to supply the crops at prices which would permit supply and demand curves to intersect at levels of production that were significant. These conditions were satisfied, it seems, by the action of a number of factors, some of which served to create a growing demand and others of which helped to facilitate supply. They were at work in every part of the Islamic world. Together, they constituted the economic framework in which the carriers of the agricultural revolution could successfully operate.

One could of course argue that demand is not a problem: supply will create its own demand. Once a plant had been introduced as an oddity, perhaps in a royal garden or in a peasant's plot, its possibilities would be seen by a few who would start to use it, and as a matter of course demand would grow. It is possible that for a few of the new plants this explanation is correct. But in the main we do not believe that the process was so simple, that what was in fact a radical change in diet and in habits of dress could occur so easily. The evidence suggests that the process of enlarging demand was more complex, more deserving of study.

In fact, many of the new crops that were at the core of the agricultural revolution were first known to the Islamic world as medicines. Many of them indeed had been described by Theophrastus (d. c. 285 B.C.) in his *Enquiry into Plants*, by Dioscorides (fl. 1st c. A.D.) in his *Materia medica*, or in other classical books of simples; and small quantities of sugar and rice, for instance, were imported

into the ancient Mediterranean as medicines but not, it is believed, grown there. Through the Arabic translation of Dioscorides and of other Greek, Roman and Indian works of medicine and pharmacy, as well as through original works on pharmacy which began appearing in Arabic by the ninth century, the inhabitants of the early-Islamic world were made aware of the alleged medicinal properties of many exotic plants. We may assume that some of these were imported and sold at high prices as medicines, though nothing is known about this trade until a later period. It is also possible that this small market for some of the new plants encouraged import substitution, and that in this way some of them came to be grown in parts of the Islamic world to supply a demand for remedies. However, we think this unlikely. The market for exotic cures must at all times have been small and composed largely of wealthy faddists willing to pay high prices. By itself it would probably not have stimulated any significant amount of import substitution, particularly as these exotic plants were difficult to grow in the Islamic world.

The next step in the enlargement of demand was therefore its transformation: instead of being thought of mainly, or exclusively, as medicines, the new plants came to be demanded as foodstuffs or, in the case of cotton, as a textile fibre. This may have come about in several ways. In very early times the migration of Indians and Persians into parts of Iraq must have been important in introducing new tastes; in slightly later times, when the new tastes had become more general in the East, the movement of easterners to settle in the more westerly parts of *Dār al-Islām* must have carried new modes of eating and dressing farther and farther westwards. Travel must also have played a part, allowing westerners to see, try, imitate and bring home the customs of the great centers of fashion in the East. But we believe that in the spreading of new tastes a crucial role was played by the uppermost classes of early-Islamic society—the rulers, their courts, and other very wealthy people in the capitals and in provincial centers. The Arab historians and chroniclers tell of great feasts offered by the eastern caliphs in which no expense was spared to regale guests with exotic dishes, sometimes made with ingredients brought from afar. Many—perhaps most—of the new plates were of Indian or Persian origin, and not a few used one or more of our plants. The caliphs, who had been aping the Sassanians and Indians, were in turn aped by their courts, and

the courts by the large class of wealthy landowners, administrators and merchants who lived in the early-Islamic capitals and great provincial cities. These were then followed to varying degrees by people farther and farther down the social scale. All the while demand for exotic produce grew.

The eagerness of early Muslims of diverse ranks to copy the *mores* of those they regarded as their betters served to enlarge demand not only vertically—that is to say, down the social ladder—but also horizontally, over space. For the eastern courts of the Umayyads and Abbasids, which were imitating still more easterly courts, were themselves imitated, as the Muslim world fragmented into a number of political entities, by new courts that sprang up in the West: in Egypt, Tunisia, Morocco and Spain. In Spain diffusion was accelerated by the collapse of the Spanish Umayyad dynasty and the appearance of a large number of petty kingdoms, each with its own court; the new Spanish courts imitated one another as well as those of the East. In short, the taste for exotic foods and modes of dress spread over space as one court copied another, and then broadened as it moved down the social pyramid. At some point demand in a particular region became great enough to justify import substitution. Local sources of supply developed. Though these may have been expensive at first, they probably cheapened as skills were acquired and the scale of production increased. With lower prices the market no doubt widened still further.

Occasionally the texts afford us glimpses of stages in this process. In the treatise of the tenth-century geographer, Ibn Hauqal, we learn of a landowner, an Emir of Mosul, who seized the right moment, after demand had become great enough, to start growing some of the new crops on his own land. We are told that he intended to plant his lands with cotton and rice and expected thereby to double his revenues. The process must have worked in much the same way elsewhere, being repeated time and again in one part of the Islamic world after another, making available what had been costly imported foods to a wider market of people. By the thirteenth century, when a few cookbooks were written that have survived, the new foods seem to be commonplace, at least in the kitchens of these for whom the books were written—in several cases, admittedly, well-to-do people. Virtually all the crops are mentioned in these books. For most there are many recipes: there were dozens of different ways of preparing eggplants; sugar had become the

main sweetening; the juice and flesh of sour oranges and lemons were widely used in preparing meats, fish, poultry and desserts; the uses of rice were legion; so were those of hard wheat. The process thus seems to have been carried to its conclusion by the time these books were written. Indeed since some of the dishes described in the recipe books were mentioned in much earlier texts, and were probably made in the same way in earlier times, the books may reflect a state in the culinary arts—and hence a broadening of demand—that had been reached some centuries before.

Something of the same process may be seen in the movement of cotton across the Islamic world. The first cotton or partially cotton cloths found in Egypt appear to be of Persian manufacture, doubtless imported by the rich who were adopting foreign fashions, perhaps not only in dress but in interior decoration. Partially cotton cloths of slightly later manufacture, dating from the eighth and ninth centuries, were probably actually made in Egypt, but still imitated Persian designs and may still have used raw cotton imported from the East. By the tenth century a good deal of cotton was probably grown in Egypt to cope with the increasing demand, though even then eastern designs were still being used. In West Africa, in the twelfth century, we catch another glimpse of a stage in the changing of taste: Al-Idrisī, writing of the towns of Silla and Takrūr, relates that “the rich wear clothes of cotton; the common people dress in wool.” This single sentence, seemingly trivial, speaks worlds to those who have ears to hear its message. It shows wealthy West Africans copying what had become the manner of dress of many Egyptians, who in turn had copied the Easterners. We do not know when cotton growing was introduced into this region where today cotton is an important crop and the principal fibre from which clothes are made, but we may suppose that it was some time after the fashion set by the rich was sufficiently widespread, and hence the demand for cotton great enough, to induce some farmers to experiment with its cultivation. In much the same way, cotton must have moved from Egypt farther west, across the north of Africa into Spain and from one Mediterranean island to another.

Facilitating Supply

But an increase in demand could not by itself bring about diffusion if there were obstacles which made the introduction of new crops too costly, which prevented supply and demand curves from

intersecting. We shall argue that the centuries following the Arab conquests saw many changes in the countryside of the Islamic world which on balance facilitated supply or—to put it another way—moved supply curves downwards.

One such change has already been noted: the advances in irrigation. Without improvements in the extent and quality of irrigation, the new agriculture could not, as we have seen, have been diffused on a significant scale. It is therefore important to search for the agents responsible for initiating and administering irrigation projects, as well as the framework of institutions which allowed or encouraged them to operate. A leading role was played by the State. Not only did it finance the repair of some of the large-scale irrigation schemes of pre-Islamic times which had fallen into ruin, but it also undertook new schemes, which substantially added to the irrigation infrastructure of the early-Islamic world. These ranged from the construction of dams, reservoir systems and canal networks affecting long stretches of great river valleys to much smaller projects which brought water to the lands of a single village. The State was also responsible for the administration of many of the larger irrigation works, which in Iraq, for instance, employed several thousand functionaries and many laborers. Of course, not all rulers or their subordinates cared equally about the operation of irrigation systems or the welfare of the communities that depended on them. With almost monotonous regularity, periods of large-scale investment and careful control were followed by periods of neglect and maladministration. On balance, however, the contribution of early-Islamic rulers to the development of irrigation seems to have been a strongly positive one, accounting for a large measure of what was achieved.

However, for medium-sized and smaller projects the initiative was often private, coming from wealthy landowners, prosperous peasant-proprietors, communities of irrigators or would-be irrigators, and associations of these communities. Even here the State must have played a fundamental part in providing the security needed to persuade others to invest. But in stimulating private initiatives certain parts of Islamic law seem to have been very important. For these the rulers and their subordinates were not primarily responsible (though they played a part in their enforcement), since in classical Islam law was for the most part not legislated or decreed but rather derived from the Koran, from the alleged doings and sayings of the

Prophet, from later attempts to extend the principles thought to underlie these, and for areas which these did not cover from custom or consensus (*ijmā'*). The Prophet himself had said much about rights to water and had settled many irrigation quarrels, and from his sayings and rulings, worked over by later jurists, there emerged a substantial corpus of irrigation law which clearly established the rights of the parties involved in all manner of disputes. Although this law did not always work towards the optimum economic use of land and water (for instance, in all but the Hanafite legal tradition land and water rights could not be disposed of separately), it was a distinct improvement over the water law of pre-Islamic times of many of the regions affected; in much of pre-Islamic Arabia, for instance, water rights were usually established and transferred by force, and in many parts whole tribes exercised collective rights over wells. By enshrining individual rights and spelling these out in detail, Islamic law undoubtedly encouraged private investors.

Other provisions of Islamic law worked in other ways to encourage investment in irrigation or to encourage the new agriculture more directly. The laws concerning taxation are here of special interest. One law provided that land watered by buckets (or in later extensions of this principle, land that was watered by water wheels or any other kind of lifting device) should pay only one-twentieth of its produce in tax instead of the normal tenth or any higher rate that might have applied. This provision surely must have given a strong incentive to introduce the water-lifting devices which became so common in the Islamic world, and which were crucial both in prolonging the irrigation season after the annual flooding of a river and in bringing water to lands that could not be reached at all by gravity flow. Another law exempted or taxed at only half the normal rate lands planted with permanent crops which had not yet begun to yield. This no doubt encouraged investment in tree crops, such as bananas, citrus, mangos and coconut palms, which ultimately yielded far higher returns than the traditional crops. Another important provision of Islamic law was the ruling of Muhammad that the person who brought into cultivation land that had been "dead" or uncultivated for more than three years should gain outright ownership of this land; moreover, such land, when it began to produce, was to be taxed only one tenth of its produce and not at any higher rate which was otherwise allowable. This law appears to have applied to tribal pasture lands as well as completely

abandoned land; it may therefore have been a powerful force favoring the expansion of sedentary agriculture over grazing, and in pushing back the frontier of settlement into the desert. More generally, the laws of taxation spelled out what taxes were to be paid by different categories of land and different kinds of crops, and compared to what went before or came later these taxes seem to have been relatively low. The landowner or tenant who introduced new techniques or new crops which promised higher returns was therefore reasonably well assured that a substantial part of the gains of his innovation would be his. At least in the early centuries of Islam, they could not easily be scooped off by capricious tax collectors or by a greedy state.

Although the records of landed estates in the early-Islamic world have not survived and we therefore have little information about agricultural organization, it does seem that some landholding arrangements also favored innovation. At the time of the Islamic conquests the large estates, which almost everywhere had come to dominate and often to monopolize agriculture, were often broken into smaller proprietorships which could be operated by an owner and his family assisted perhaps by a few paid workers. Large estates remained, of course, and new ones were built up, but for some centuries the large estate had to compete with an alternative form of landholding in the shape of larger and smaller peasant proprietorships. Competition was intensified by the existence of much smaller, heavily irrigated "garden" areas in the immediate hinterland of nearly all the major cities and elsewhere, on which many of the new crops were also grown and the new techniques of farming applied. These were probably both owner-operated and tenant-operated. The existence, therefore, of three very different forms of agricultural undertaking, and the inevitable competition between them, probably was important in stimulating innovation by landowners and tenants alike.

The larger estates, moreover, seem to have been relatively free of the retrograde features which kept productivity low and discouraged innovation on the estates of late Rome, of Byzantium and of medieval Europe. For example, the early-Islamic estate does not seem to have had a demesne, in the sense of an important part of the estate which the owner operated for his own profit with the help of involuntary tenant labor. Holdings of both owners and their tenants seem to have consisted of consolidated blocks or a small num-

ber of fragments: there was nothing to correspond to the open-field system of northern Europe. Nor do we learn of any cultivated land over which peasants exercised common or collective rights, or of any operations which, like the plowing on the manors of northern Europe, required co-operation (except, of course, the construction and upkeep of irrigation works). Finally, the labor that was required on the land was generally supplied by sharecroppers; and of all systems of mobilizing labor to farm large estates sharecropping was probably the one which most encouraged innovation on the part of landowners and their tenants, both of whom stood to gain from increases in productivity. To what extent paid labor was important is not clear, though some of the documents from Egypt do mention hired workers. What is certain, however, is that agricultural slaves, serfs and tenants bound to the soil or to a landowner were rarely found. The agricultural labor force was by and large free and, it seems, mobile. It tended therefore to move from less to more profitable undertakings: presumably from the old agriculture to the new, and from long settled, densely populated areas into new lands offering new opportunities. Indeed the apparently great mobility of agricultural labor—which is but one aspect of the mobility of all classes of people in the world of early Islam—may in another way have encouraged the diffusion of the Arab agricultural revolution. The Yemeni, Hejazi, Persian, Iraqi and Syrian peasants who migrated westward to settle in Egypt, the Maghrib and Spain may have had among their numbers the carriers of new crops and new farming techniques. As we know from the study of industrial technologies, difficult skills are most readily diffused by the migration of those who possess them. Only with greatest pains are they learned afresh by other people in other places.

Another kind of landed undertaking may also have played an important role in diffusing the agricultural revolution. This was the royal garden. Found almost wherever a ruler had his seat, and in other places as well, these seem to have been active in introducing exotic plants, including, we may suppose, some of the new crops at the core of the new agriculture. They may also have developed strains of the new crops better suited to new climates and new soils, and have been focal points in the disseminating of information about how these were to be grown. We are told, for instance, that ‘Abd al-Raḥmān I of Spain collected in his garden rarities from every part of the world. He even sent agents to Syria and other

parts of the East to procure new plants and seeds. A new kind of pomegranate was brought to Spain through his garden. The date palm, too, was probably introduced or re-introduced in the same way. By the tenth century the royal gardens at Cordoba seem to have become botanical gardens, with fields for experimentation with seeds, cuttings and roots brought in from the outermost reaches of the world. Other royal gardens in Spain also seem to have become, as well as places of amusement, the sites of serious scientific activity. Ibn al-Abbār relates that the King's garden in Toledo, the famous Huerta del Rey, was at least in part an experimental farm in which eastern plants were acclimatized, and new strains, perhaps more suitable to Spanish conditions, produced. An important, recently discovered geographical manuscript, that of al-'Udhri, states that al-Mu'tašim, a Taifa king, brought many rare plants to his garden in Almeria; these, we are told, included bananas and sugar (both of which, however, we know were already grown in other parts of Spain). At the other end of the Islamic world, in Tabriz, we find the garden of the Il-Khans being used to acclimatize rare fruit trees from India, China, Malaysia and Central Asia. Another sign of the serious nature of these undertakings is the fact that such gardens were often in the charge of leading scientists: that of the Il-Khans was directed by a Persian botanist who wrote a book on the grafting of fruit trees; the Huerta del Rey in Toledo was in the charge of two of Spain's leading scientists, Ibn Baššāl and Ibn Wāfid, both of whom wrote important manuals of agriculture, the partial texts of which have recently been discovered. Ibn Wāfid was also the author of a book of simples, which gives, *inter alia*, the names and uses of many of the new plants being introduced into Spain. After the fall of Toledo in 1085 both scientists moved to the south of Spain and continued their work there; Ibn Baššāl planted another botanical garden in Seville for his new patron, al-Mu'tamid, the Taifa king.

Whether the manuals of farming were also important in diffusing new crops and new agricultural practices is more difficult to say. Quite possibly they were not. We cannot know how widely they circulated nor what kind of reader they reached, but their usefulness was clearly reduced by their relatively late appearance. The earliest manuals, *The Nabatean Book of Agriculture* and *The Greek Book of Agriculture*, date from the beginning of the tenth century and must at first have been read primarily in the eastern part of the

Islamic world. But the accounts of geographers and other writers of the tenth century show that by then the revolution was well under way in the East and was perhaps largely completed. These manuals must therefore have played only a secondary role in popularizing practices already known to enlightened peasants and landowners. In this way they may have broadened the scope of a revolution that was already well established. In the western parts of the Islamic world, which were touched by the revolution slightly later, these early manuals could have been more important if in fact they had a significant western readership in the half century after their appearance. But by 961, the date of *The Calendar of Cordoba*, the main elements of the revolution were to be found in parts of Spain and probably all over the West; hence these early eastern manuals could at best have played some role only over a period of half a century. By the time the Spanish manuals appear in the eleventh century the revolution must have been a *fait accompli*, needing perhaps only secondary diffusion into areas where backward peasants and landowners had not heard its message. The *summa* of Spanish agriculture, the *Kitāb al-filāḥa* of Ibn al-ʿAwwām, written in the twelfth century, came at a time when the classical age of Islam was already over in the East and when Muslim Spain, a latecomer to the Golden Age, was itself on the brink of decline.

III

The end of the tale is the story of the decay of Islamic agriculture in general and the waning importance of many of the new crops in particular. It begins at different times in different places. As early as the ninth century, settlement retreated from parts of the Hejaz and Transjordan. Although the reasons for this precocious abandonment of land are still obscure and may have had nothing to do with what was to follow—indeed it ran counter to the immensely successful Abbasid policy of *ʿimāra*, or development of the economy through dense settlement of the land—it may have been the first sign of a process that was later to become more general. From the eleventh century onwards decline became more evident as almost every part of the Islamic world was overrun by successive waves of invaders: by the Seljuks, the Crusaders, the Ayyubids, the Mongols, and the Ottomans in the East, and by the Banū Hilāl, the Almoravids, the Almohads, the Normans, and the Spanish *reconquistadores* in the

West. Although the agricultural history of the Islamic world under its new conquerors is largely unwritten, one is able to glimpse stages in its decay. It was particularly evident at the time of invasions which often destroyed irrigation works and caused peasants to take flight. But the aftermath of invasions sometimes had more long-lasting effects. As they had come from regions where agriculture had made less intensive use of the soil, the conquerors were on the whole unsympathetic to the kind of agriculture which the early-Islamic world had so brilliantly created. They tended to introduce systems of farming and land tenure which favored cereal crops and grazing, and which could accommodate only with difficulty specialty crops. Matters were made worse in some areas by the failure to maintain the irrigation works, by the excessive taxation of the peasantry and the corruption of the tax collectors, and probably by a breakdown of the rule of law. Military benefices, known as *iqṭā'*, became increasingly prevalent in many regions at the expense of other forms of taxing and administering the land; their holders enjoyed different kinds of immunities which allowed them to reduce the peasantry to varying degrees of dependence, if not actual serfdom. Long-term development of the land and even maintenance of existing capital were often sacrificed to higher, more immediate revenues. Land in many areas came to be used less intensively. Some was abandoned.

The final blow came from the circumnavigation of Africa and the discovery of the New World. On old and new continents, with large tropical and semi-tropical areas, the new crops which had been introduced into the early-Islamic world could be grown more cheaply than in the Middle East and the Mediterranean. In spite of high transport costs, rice, cotton, sugar, indigo and some of the other new crops began coming from Asia and the Americas into the Islamic world and its European export markets. By the end of the seventeenth century cotton, rice and sugar had largely disappeared as crops from the Mediterranean basin, where they had once been so important; these crops, long ago introduced into the Islamic world as import substitutes, had in turn been replaced by imports. Their disappearance is part of the general economic decline of the Mediterranean basin in this period. The voyages of discovery did result in the diffusion of many new crops over the earth's surface, some of which were to be of great economic importance, and offered to certain nations many other kinds of economic opportuni-

ties. But although maize, tobacco and tomatoes spread through the Islamic world in the centuries after the New World was reached, the possibilities of the new continents seemed to have little interest to Muslims—those people who had once been so eager to snap up any novelty that could give profit or amusement. In the process of its decay, the Islamic world had lost its receptivity to the new and had closed in upon itself.

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APPENDIX

BIBLIOGRAPHICAL NOTE

As the full bibliography used in my research is vast, I can list here only some of the main primary sources. The most important of these are the Arab farming manuals, of which about fifteen have survived from the pre-Ottoman period. The following are the key authors and texts: Ibn Waḥshīya (?) (wr. 903/4?), *Al-filāḥa al-nabaṭīya* (The Nabatean Book of Agriculture), Dār al-Kutub Cairo, Agric. Ms. 490, a work of greatest importance, in spite of its uncertain authorship, which has been little studied until now on account of its long and very difficult text and the absence of an edition; “Qusṭūs al-Rūmī” (tr.? early-10th c.), *Al-filāḥa al-rūmīya* (The Greek Book of Agriculture) (Cairo, 1876), a work which clearly relies on earlier Byzantine traditions, to which, however, very important additions were made, probably at the time of compiling the Arabic edition; Abū al-Khair (fl. 11th c.?), *Kitāb al-filāḥa*, B. N. Paris, Ms. 4764 fol. 61-180; Ibn Baṣṣāl (?) (d. 1105), *Kitāb al-filāḥa*, ed. & tr. J. M. Millás Vallicrosa & M. Aziman (Tetuan: Instituto Muley el-Hasan, 1955); and Ibn al-‘Awwām (fl. 12th c.) *Libro de agricultura*, ed. & tr. J. A. Banquieri, 2 vols. (Madrid, 1802) Information about these and other surviving Arabic agricultural manuscripts is given in the following: C. Cahen, “Notes pour une histoire de l’agriculture dans les pays musulmans médiévaux,” *Journal of the Economic and Social History of the Orient*, XIV (1971), 63 ff.; J. M. Millás Vallicrosa, *La ciencia geopónica entre los autores hispanoárabes* (Madrid: C.S.I.C., 1954); and *Encyclopedia of Islam*, 2nd. ed., voce “Filāḥa.” Until recently, however, no serious studies were made of the agricultural practices described in the texts. This gap had now been partly filled by the important work of Dr. Lucie Bolens of the University of Geneva, who has studied particularly the sections on soils and irrigation in the writings of the Hispano-Muslims. See L. Bolens, *Les méthodes culturales au Moyen Age d’après les traités d’agronomie andalous: traditions et techniques*, Thèse de doctorat du 3e cycle présentée à l’Université de Paris, I; “L’eau et l’irrigation d’après les traités d’agronomie andalous au moyen-âge (XIe-XIIe siècles),” *Options*

méditerranéenes (1972), 64 ff; and "Engrais et protection de la fertilité dans l'agronomie hispano-arabe. XIe-XIIe siècles," *Etudes rurales*, XLVI (1972), 34 ff. Apart from the agricultural manuals, the works of a large number of geographers and travelers have been invaluable; a survey of the literature up to the middle of the eleventh century is given in A. Miquel, *La géographie humaine du monde musulman* (Paris/The Hague: Mouton, 1967) pp. xiii-1; but among the later writers not covered in this book should be mentioned al-Bakrī, al-Idrīsī, Ibn Batūta, al-Maqrīzī, Nāṣir-i Khusrau and al-'Umarī (*q.v.* in *Encyclopedia of Islam*). Numerous books of simples and works on medicine have also been useful, of which the most important is Ibn al-Baitār (d. 1248) *Traité des simples*, tr. L. Leclerc, Notices et extraits des manuscrits de la Bibliothèque Nationale, XXIII, XXV, XXVI (1877-83); other useful works in this area are listed in R. Y. Ebeid, *Bibliography of Medieval Arabic and Jewish Medicine and Allied Sciences* (London: Wellcome Institute, 1971). Finally, three other works are indispensable: Anon. (wr. 961) *Le calendrier de Cordoue*, ed. & tr. C. Pellat (Leyden: Brill, 1961), an agricultural calendar describing the tasks performed in different months; Ibn Mammātī (d. 1209), *Kitāb qawānīn al-dawāwīn*, ed. A. S. 'Atiya, (Cairo: Ministry of Agriculture, 1943), a manual for the use of functionaries which contains much information on farming practices; and al-Nuwairī (d. 1332), *Nihāyat al-arab fī funūn al-adab*, 18 vols. (Cairo: Dār al-kutub, 1923-65), an encyclopedic work.