Agronomic Treatises of the Medieval Muslims
(10th century – 12th century A.D.)
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Before discussing the Islamic history of filāḥa, one should know the literal and technical meanings of this word. The word filāḥa has been derived from the root words fā, lā and ḥa. Ibn Manẓūr mentions the literal meaning of the word as follows:

“Al-Falāḥ and al-Falāḥ: Prosperity or success; safety or security; and continuance or permanence in a good or prosperous state and in the enjoyment of ease, comfort, or the blessings of life and continuance of good. It is stated in the Ḥadīth of Abī Daḥḍāh: Bashsharaka Allāhu bi Khayrin wa Falaḥin i.e. May Allah give you the glad tidings of prosperity and continuance of the blessings of life.”

“Another meaning of al-Falāḥ is to cleave, split or cut. Falaḥa al-Shay’a: He split it apart. The poet said: “Indeed your horse knew that I am al-Sahsah, and verily the iron is cut with the iron.”

“Al-Falāḥ is the transitive verb. Falaḥtu al-Arḍa is said when I ploughed or tilled it for cultivation. Al-Fallāḥ: A plougher, tiller or cultivator of land. He is called fallāḥ because he ploughs (cuts the surface of) the land. And his work is called al-Filāḥah which means tilling, cultivation, or ploughing. In the Ḥadīth of ‘Umar comes ittaqū Allāha fī al-fallāḥīna: Fear Allāh in the matter of cultivators or tillers or ploughers those who cut the surface of land.” (1)

In technical term, the concept of filāḥa, according to Taufic Fahad, is “the culture and care which plants need.” (2) In the view of Ibn Khaldūn:

“It concerns the study of the cultivation and growth of plants through irrigation, proper treatment, improvement of the soil.” (3)

While mentioning His bounties on mankind, Allāh Almighty has mentioned in the Surah al-Mulk that He has tamed the earth for us. The surface of the earth has been made such by Allah that tilling and plantation is possible. If the earth had been made of stone, gold or silver, it would have been impossible to grow anything from it. The verse says:

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“It is He who made the earth tame for you - so walk among its slopes and eat of His provision - and to Him is the resurrection.” (4)

The practice of tilling of the land has also been mentioned. While reminding the end of previous disobedient nations, Allāh Almighty has told that they were strong and used to plough their land. The verse in the Surah al-Rūm says:

“They were greater than them in power, and they ploughed the earth and built it up more than they have built it up.” (5)

Gardening has been mentioned in an incident told in the Surah al-Kahf. One of the two brothers mentioned in the surah was given gardens. The verse says:

“And present to them an example of two men: We granted to one of them two gardens of grapevines, and We bordered them with palm trees and placed between them (fields of) crops.” (6)

The Holy Prophet (peace be upon him) urged the Muslims to cultivate land in a famous hadith. He said:

"Whoever has land, let him cultivate it or give it to his brother to cultivate, and not lease it to his brother." (7)

Based on the teachings of the Holy Qur’ān and ḥadīth, Muslims of the medieval period had shown great interest in the field of agronomy. The Islamic tradition of agronomy of the medieval period begins with a monumental work, Al-Filāḥah al-Nabatīyyah (Nabataean Agriculture), which is claimed to be pre-Islamic in origin and has translated from ancient Syriac into Arabic by Ibn Waḥshiyya (d. 318/930–1) whose full name was Abū Bakr Aḥmad b. ‘Alī b. Qays al-Kaldānī. He was from Qusayn near Kūfah in Iraq, and also made a long stay in Egypt. He wrote that he searched for the science works of his ancient ancestors until he found them and translated them into Arabic. (8) Ḥāji Khalīfah claims that he was one of the translators who were employed by the Abbasid Caliphs to translate the ancient Mesopotamian work (Nabataean) into Arabic. (9)

Al-Filāḥah al-Nabatīyyah (Nabataean Agriculture)

“Al-Filāḥah al-Nabatīyyah (Nabataean Agriculture)” is a tenth-century treatise by Ibn Waḥshiyya which reflects the agricultural practice of central Mesopotamia (around Kūfah). This is based on works written by a group of scholars who were the ancient inhabitants of Mesopotamia. In the end, the work was put together by an author called Quthāmā. According to
Hämeen-Anttila, “its contents are a mixture of practical advice on agriculture, theoretical speculation on the influence of stars and elements on plants, together with charms and magical procedures and a huge amount of folklore, myths, ancient stories and religious information”.(10)

The authenticity of the Nabataean corpus has been disputed by the scholars. Étienne Quatremère (1835) and Daniel Chwolsohn (1850s) acclaimed it as a genuine piece of Babylonian literature. However, Alfred von Gutschmid (1861) and Theodor Nöldeke (1876) criticized it due to inconsistencies present in it.(11) The botanist E.H.F. Meyer, though admitted that the text was a forgery, had accepted its value of the work for botanical and agricultural studies.(12) Hämeen-Anttila concludes, “it contains much material that has to be genuine in the sense that it is not fictitious but describes the existing rituals, beliefs and magic of the population of Iraq, either in the centuries before the Islamic conquest or soon after it.”(13)

The Nabatean Agriculture provides the basis for ancient and medieval agronomy. This is a significant book on plants and agriculture which encompassed much of the information of ancient Chaldeans regarding their principles of agriculture, the types of crops they used to plant, the ways of storage, the methods of use and protection from pests. At many places, he also tells new ways of agriculture.(14)

A critical edition of this compendium has been edited by Taufic Fahad in 1993 entitled: “Al-Filāḥah al-Nabaṭiyah: Al-tarjamah al-manḥilah ilā Ibn Waḥshīyah, Abū Bakr Ḥamd ibn ’Alī ibn Qays al-Kasdānī” published by al-Maḥad al-‘Ilmī al-Faranṣī lil-Dirāṣāt al-‘Arabīyah, Damascus.”(15) According to this edition, “it consists of over one hundred and fifty chapters of varying lengths. The first section deals with olive trees. The second one deals with water which conditions agriculture. The third one deals with aromatic floral plants. The fourth one deals with trees and bushes with medicinal properties. The fifth section can be called a handbook for the agriculturalists. The sixth one deals with leguminous plants and grains. The seventh one studies wild plants. The eighth one is dedicated to phytobiology and the morphology of plants. The ninth one is dedicated to vegetables. The tenth one is dedicated to the vine. The eleventh concerns trees: fruit trees and forest trees. The twelfth is dedicated to autogenesis of plants and to the art of reproducing or imitating nature. The thirteenth is dedicated to date palm.”(16)

Next important contribution to the field of agronomy by a Muslim agronomist is “Majmūʿ fī l-Filāḥa”. This treatise was compiled by an Andalusī, Ibn Wāfid (d. 467/1075), whose full name was Abū al-Muṭarrif ʿAbd al-Raḥmān b. Muḥammad b.ʿAbd al-Kabīr al-Lakhmī. He lived in
Toledo in the days of Ibn Dhū al-Nūn. He was born in Dhū al-Ḥijjah 387/997 and was still alive in 460/1067. He devoted himself to the study of Galen and also read Aristotle and other philosophers.(17)

**Majmū‘ fi ’l-filāḥa (Compendium of Agriculture):**

An agricultural treatise, *Majmū‘ fi ’l-filāḥa* (Compendium of agriculture) has been attributed to Ibn Wāfid. Interestingly, there is no extant Arabic manuscript of this work with the name of Ibn Wāfid as author, but there is a late 14th/early 15th century C.E. copy of an earlier Castilian translation of the Majmū‘ attributed to a certain ‘Abel Mutariph Abel Nufit’, who according to Millás Vallicrosa must be identified with Aḥū ’l-Muṭarrif ibn Wāfid.(18) This is supported by the statement of Ibn al-Abbār:

“He (Ibn Wāfid) wrote a very interesting compendium of agriculture, having mastered all aspects of the science, and was responsible for planting the famous garden of the ruler Al-Ma‘mūn in Toledo.” (19)

Ruggles describes it as: “the compendium is divided into eighty-seven chapters plus an agricultural calendar towards the end. The chapters deal with soil types; water and how to detect its presence in the soil; the most suitable seasons for building farmhouses; fertilizers; seed selection; things that damage grain (such as hailstorms); when to sow wheat and barley; when to reap; the threshing barn; granaries and bakeries; how to select sites for vineyards; choosing vine shoots to plant and how to plant them; olive oil preparation; and the soil preparation for and sowing of lettuce, cabbage, chard, turnips, radishes, onions, leeks, garlic, celery, basil, cucumbers, melons, and sugarcane. More than fifty chapters of the original text are missing. Then, there is a set of specific instructions on when to plant, prune and harvest each type of plant and tree. It ends with a section on bee-keeping, pigeon-keeping, and pesticides such as myrtle and cumin.”(20)

The author of this text does not mention practical agricultural experience of his own, nevertheless, harbours a prodigious knowledge of the subject. Thomas Glick is of the view that the Majmū‘ has influenced the great work of agronomy, the *Obra de Agricultura* of Gabriel Alonso de Herrera (6th century C.E.). “He is one of the five frequently quoted works by Herrera. He has been cited one hundred and two (3 percent) times by him.”(21)


Another agronomist of Andalusia was Abū ‘Abd Allāh Muḥammad b. Ibrāhīm (1050 -1100 CE) known as Ibn Baṣṣāl al-Ṭulayṭūlī. He used to serve at the botanical garden of king al-Ma‘mūn b. D hil Nūn in Toledo. Under the instruction of his mentor Ibn Wāfid, he journeyed to the east and collected seeds and plants for the botanical garden. After his return to Toledo, he applied the information he had gathered during his journey. When the Castilian king Alfonso VI (1085) conquered Toledo, he took Ibn Baṣṣāl with him to Seville where he was given the charge of a botanical garden by al-Mu‘tamid b. ‘Abbād. The tradition of agronomy in Seville was characterized by him and his successors Abū al-Khyar al-Ishbīlī, Ibn al-Lūnquh and al-Ṭighnarī.(25)

Ibn Baṣṣāl penned the book Kitāb al-Fīlāḥa during his stay in Toledo. The original book is not available, but the manuscripts of an early summary are available. The summary is entitled as “Kitāb al-Qaṣd wa‘l-Bayān.” This summary was translated into Castilian probably in the court of Alfonso X of Castile (r.1252-1284). Julio Samso describes it as: “the work deals with waters, soils, fertilizers, preparation of the land, the cultivation of trees and other vegetables. In the end there is some advice on domestic economy.”(26)

Kitāb al-Qaṣd wa‘l-Bayān (The Book of Concision and Clarity):

The abridgement of Ibn Baṣṣāl’s work comprises sixteen chapters: “The first chapter examines water of four kinds (rain water, river water, spring water, and well water). The second chapter examines the ten types of lands and soils (soft, heavy, mountain, sandy, black manure land, white, yellow, red, rough and stony land, and, reddish sandstone land). The third chapter deals with manures of seven kinds (equine, human, sweepings and refuse, that from sheep, and pigeons, ashes from bathhouse furnaces, and, lastly, artificial compost made from grasses, weeds and dry leaves). The fourth chapter discusses the indicators by which the farmer can determine
the quality of land. He advises on the ways to prepare land and organize it for cultivation, and how to ensure that water circulates properly, if it is irrigated.”(27)

“The fifth chapter comprises fifty-three sections and examines the species of trees, including fruit-trees and explains different methods of propagation by seed or stone, shoots, cuttings and grafts. The next chapter is brief and sheds more light on some methods of propagating the trees already mentioned. The seventh chapter is also very short and deals with the pruning of trees.”(28)

“The eighth chapter is devoted to the operation of grafting. Ibn Baṣṣāl discusses in great detail the determinants of grafting and discusses the five general types of graft: the Roman graft (between bark and wood), cleft graft, tube graft, shield graft, and drill or awl graft. The ninth chapter complements the previous chapter in discussing more of grafting, especially in making grafts between trees of very different natures, for example, between the olive and the fig tree.” (29)

“The tenth chapter is very long and includes the cultivation of herbaceous plants, grains and vegetables. However, the chapter does not include the cereals: wheat, rye, barley, etc. The eleventh chapter continues with the cultivation of plants used as spices and flavourings, such as cumin, caraway, fennel, anise, coriander, etc. The twelfth chapter concerns the cultivation of plants typical of larger gardens and irrigated land and the next one is devoted to bulbs and root plants. The fourteenth chapter is given to the cultivation of leaf vegetables. The fifteenth chapter deals with aromatic plants. The last chapter gives some useful knowledge concerning water, wells, the preservation of fruits, etc.”(30)

Ibn Baṣṣāl’s treatise, Kitāb al-Qaṣd wa’l-Bayān, was translated into Castilian in the 13th century. It was edited by Millás Vallicrosa in 1948 as: “La traducción castellana del ‘Tratado de Agricultura de Ibn Baṣṣāl which was reprinted in 2001 under the title Agriculture. Texts and Studies 5 in (Natural Sciences in Islam 24) edited by Fuat Sezgin and published by Institut für Geschichte der Arabisch-Islamischen Wissenschaften, Frankfurt. In 1995, an edition entitled Libro de Agricultura with Spanish translation and notes by J.M. Millás Vallicrosa & M. Aziman was published by Instituto Muley El Hassa, Tetuan”. (31)

A contemporary of Ibn Baṣṣāl was Ibn Ḥajjāj. Born in Seville, his full name was Abū ʿUmar Aḥmad b. Muḥammad b. Ḥajjāj al-Ishbīlī. He wrote a treatise entitled Al-Muqni‘ fī ’l-fīlāṭa (Sufficiency in Farming) in 466/1073. (32)
Al-Ma'qna 'fi 'l-filâha (Sufficiency in Farming)

Ibn Ḥajjāj was the most learned of the Andalusi agronomists. No complete copy of his work is available to us today, but he is the principal source of Ibn al-'Awwām who gives much respect to him as he mentions in the introduction of his book:

“When I come to discuss the cultivation of lands, I always give precedence to the principles established by the Shaykh al-Khatīb Abū 'Umar Ibn Ḥajjāj in his book, which has as its subject the theories of the ancients” (33)


Taufic Fahd comments about it: “Ibn Ḥajjāj’s work is important as it introduces in the Arabic agronomy the Latin agronomic tradition represented by Varro (first century BC) and Columella (first century AD). He quotes frequently from the classical agronomic texts, citing 23 authors in an indirect manner. His most frequent citation (28 times) is Yūniyūs who is probably Junius Moderatus Columella of Cadiz, or Vindanius Anatolius of Beirut.” (36) There also exist some similarities between the works of Columella and Ibn Ḥajjāj in the manner of citation, in the introduction, and in terms of knowledge and agricultural practices. (37)

Another Spanish contributor is Abū al-Khayr al-Ishbīlī, the Shajjār, who wrote the book “Kitāb al-Filāḥa” (Treatise on Agriculture) somewhere in 1073. Not much is known about his life except that he was born in Seville. (38)

“Kitāb al-Filāḥa” (Treatise on Agriculture)

Abū al-Khayr al-Ishbīlī was a disciple of Ibn Baṣṣāl and often cites him along with other ancients. Although his treatise exists in an incomplete form, but gives valuable information on the cultivation of crops and plants. He is esteemed by Ibn al-'Awwām for his knowledge of soils, irrigation, the construction of wells, and cultivation of olives. (39) For the cultivation of olives he suggests three ways: “by cuttings, by layering, and that of sowing, or propagation by stone or pit.” According to him, “flax thrives on sandy, well-rested land. It needs a very loose soil, requiring several successive ploughings at judicious intervals. The cotton plant likes loose, broken up ground and the rainy season is the most favourable for sowing. Madder is
sown in March which prefers chalky-clay soil, a little sticky and well-
manured.” (40)

Another disciple of Ibn Baṣṣāl was Abū ‘Abd Allāh Muḥammad b. Mālik al-Murrī, Al- Ṭīghnarī (d. after 1087). He lived at the court of Abū ‘Abd Allāh b. Buluggīn b.Badis (r. 1073-1090) who ruled over Granada. His treatise on agriculture entitled Kitāb Zuhrat al-Bustān wa-Nuzhat al-Adhhān (Book of the glory of the garden and recreation of the minds) comprises twelve parts and three hundred and sixty chapters.41 He was not only a theoretical agriculturist, but carried out his experiments in the royal gardens of the Al-Sumādīhiya palace in the tāʾīfa kingdom of Almería.(42)

*Kitāb Zuhrat al-Bustān wa-Nuzhat al-Adhhān (Book of the glory of the garden and recreation of the minds)*

The author has dedicated his book to the Almoravid governor of Granada Abū 'l-Ṭāhir Tamīm b. Yūsuf b. Tāshfīn (r. 1107-10 and 1121-26). García Sánchez concludes that it was written in the first decade of the 12th century. There is only one copy of the original text of Al-Ṭīghnarī’s treatise which has been edited with introduction by E. García Sánchez in 2006. According to this edition, “there is a prologue which discusses general matters concerning agriculture. After the prologue, the treatise begins with an agricultural calendar of an astronomical and meteorological nature which includes references to magic, local traditions, the experiences of farmers. Then the main body of the work discusses the following subjects: Soils, manures and fertilizers, hydrology, general practical rules for farmers, domestic economy, the propagation of various trees and shrubs, treatment for the prevention and cure of their diseases and pests, as well as the care and methods needed to cultivate them successfully. At the end of the section devoted to each plant, the author describes its medicinal and nutritional value. He has also discussed grafting, the planting and cultivation of various cereals, vegetables and garden plants, etc.”(43)

The most notable Spanish agronomist of the medieval period is Ibn al-‘Awwām al-Ishbīlī, the author of the outstanding treatise on agriculture *Kitāb al-Filāḥa*. His full name is Abū Zakariyā Yāḥyā b. Muḥammad b. Aḥmad b. al-‘Awwām and he flourished during the 12th century, at Seville.44 He is the only agronomist mentioned by the historian Ibn Khaldūn,(45) and is noted too by the early 15th century encyclopaedist Al-Qalqashandī.(46) But both of them do not give his biographical details.

*Kitāb al-Filāḥa:*

Ibn al-‘Awwām’s *Kitāb al-Filāḥa* is the most significant Andalusi treatise on the subject of farming. It was the first Andalusi treatise to be published and translated into a modern language, initially into Spanish by Banqueri in
1802, then into French by Clément-Mullet in 1864–67, and subsequently into Urdu in 1927.(47)

Thomas Glick describes it as: “This is a huge compendium which is considered to be the most comprehensive agricultural treatise. He has gathered all the knowledge from all previous agricultural traditions and treatises. It contains one thousand nine hundred direct and indirect citations, a fact which makes it an enriched source of information on agronomy. 32.5% of these citations are to the Byzantine sources, especially the Geoponika of Cassianus. 31% are to the near eastern sources, especially Ibn Waḥshiyya and 36.5% are to the earlier Sevillian agronomists. In the areas of arboriculture, olive and grape cultivation, and cereals his reliance is mainly on the classical sources. The part on soils and fertilizers is taken mainly from the Near Eastern sources. And Andalusi sources have been used in sections on irrigation, grafting and pruning, garden vegetables, condiments and flowers.”(48)

Apart from the citing his predecessors, he often adds his own observations and experiences. For example, “he records his experiments in grafting the wild olive of the mountains with the domesticated olive of the plain, and his successful cultivation of saffron, under irrigation, in the mountains.”(49) Regarding his experiments he says:

“As for my own contribution, I put forward nothing that I have not first proved by experiment on repeated occasions” (50)

There are thirty four chapters of Ibn al-‘Awwām’s treatise which expound the following themes: “the nature of soils, irrigation techniques, working the land according to its specificities, grafting, cultivation of fruit trees, market, vegetable and flower gardening, pruning and trimming, etc. Certain chapters are on animal husbandry. He also wrote on drip irrigation, rice farming, artificial fertilization of date palms, acclimatization of vegetables and spices like cucumbers, gherkins and saffron.”(51) Sarton comments on the book in the following words:

“Ibn al-Awwām’s treatise deals with 585 plants, and explains the cultivation of more than fifty different fruit trees. It contains striking observations on the different kinds of soil and manure and their respective properties, on various methods of grafting, on sympathies and antipathies between plants, etc. The symptoms of many diseases of trees and vines are indicated as are also methods of cure.”(52)

Greene remarks: “There are two early Arabic texts with Spanish and French translation of the Kitāb al-Filāḥa. The Spanish translation came in 1802 in 2 volumes by J. A. Banqueri, Madrid entitled Libro de agricultura. The French translation came in 1866 in 2 volumes by J.-J. Clément-Mullet
entitled *Le Livre de l’Agriculture*. Sarton considered the text and translations unsatisfactory. However, both the Spanish and French translations have been revised and republished as:


A previously unpublished part of the text about pruning grapevines was published and translated into Italian by Sul Taglio in 1889. Some extracts from Ibn al-‘Awwām have been translated into English and published as: Lord, P. (trans.) (1979). *A Moorish Calendar: from the Book of Agriculture of Ibn al-Awam*. Wantage: The Black Swan Press.

**Conclusion:**

The medieval era marks the period of greatest Muslims’ achievements in different disciplines of knowledge. One of such disciplines is agronomy. By the end of the ninth century A.D., most parts of land under the Islamic rule were undergoing through the process of extension of agriculture. Much of the land was being cultivated, many new crops were introduced, the use of irrigation techniques was widespread and there was a significant rise in the productivity of agricultural land. Although the agriculture was flourishing throughout the Muslim world, but it was al-Andalus where it reached its glory.

The Muslim tradition of agronomy can be traced back to a significant treatise authored by Ibn Waḥshiyya entitled “*Al-Filāḥah al-Nabatīyyah*”. This is a voluminous book comprising practical advice on agriculture coupled with a huge amount of folklore and magical procedures. Between the tenth to the twelfth century A.D., especially during the Tāʾifa kingdom in the second half of the eleventh century, many books on *filāḥa* were written down by Andalusi agronomists: Ibn Wāfid, Ibn Baṣṣāl, Ibn Ḥajjāj, Abū al-Khayr al-Ishbīlī, al-Ṭīghnarī and Ibn al-‘Awwām. They were the inheritors and transmitters of the tradition of the ancients including Byzantines, Romans, Greeks, Carthaginians and Chaldeans. They tested the inherited knowledge and compared it with their own experimental findings. Their books were both theoretical discussions on agronomy and practical manuals of the Muslim agronomists.

Ibn Wāfid authored an agricultural treatise “*Majmūʿ fī ‘l-filāḥa*”, a compendium consisting of eighty seven chapters with an agricultural
calendar towards the end. Ibn Baṣṣāl’s treatise, “Kitāb al-Qaṣd wa’l-Bayān” comprised sixteen chapters dealing with agriculture with some advice on domestic economy in the end of the treatise. “Al-Maqna ‘fī ‘l-fīlāḥa” by Ibn Ḥajjāj was so important in the eyes of Ibn al-‘Awwām that it became the principal source of his treatise. Ibn Ḥajjāj introduced in the Arabic agronomy the Latin agricultural tradition represented by Varro and Columella. Ibn Baṣṣāl’s disciple Abū al-Khayr al-Ishbīlī gave valuable information about the cultivation of crops and plants in his treatise “Kitāb al-Fīlāḥa”. Another disciple of Ibn Baṣṣāl, al-Ṭīghnarī was a practical agriculturalist who authored the book “Kitāb zuhrat al-bustān wa-nuzhat al-adḥān” in 12 parts and 360 chapters. The most notable among the Andalusi agronomists was Ibn al-‘Awwām. He gathered all information about the agriculture from Byzantine, Near Eastern and Sevillian sources. There are thirty four chapters of his treatise “Kitāb al-Fīlāḥa” which deal with 585 plants, and it explains the cultivation of more than fifty different fruit trees.
References

4. Al-Qur’ān, 67:15
5. Al-Qur’ān, 30:9
6. Al-Qur’ān, 18:32
11. Ibid., p.4
12. Ibid., p.5
13. Ibid., p.6


23 Ibid.

24 Ibid.


26 Ibid., p.312


28 Ibid.

29 Ibid.

30 Ibid.

31 Ibid.


36 Taufic Fahd, Botany and Agriculture, p.846

37 Ibid., p.847


39 Ibid.


Al-Zarkalī, Al-ʿĀlīm,8:165; Al- Nuwayhī, Al-ʿĪlm al-Nabāṭ ʿind al-ʿArab, p.176


Glick, Thomas F., “Agronomy”, p.12-13


Ibn al-ʿAwwām, Clément-Mullet 1866, I, p. 9

Ahmed Djebbar, “Arab Agronomy: from the science of the soil and plants to the art of the garden” in Arab-Muslim Civilization In The Mirror of The Universal: Philosophical Perspectives, published by UNESCO in 2010, p.311

Sarton, George, Introduction to the History of Science (Baltimore: The Williams and Wilkins Company, 1931) 2:425-25


Sarton, Introduction to the History of Science, 2:44


Greene, Edward Lee, Landmarks of Botanical History, Part 2, p.439