Delpinoa, n.s. **46**: 85-93. 2004

# Federico Delpino's scientific thought and the birth of modern biology in Europe

G. Aliotta[1], A. Aliotta[2]

[1]Dipartimento di Scienze della Vita, Seconda Università degli Studi di Napoli, Via Vivaldi 43, 81100 Caserta, Italy; [2]Facoltà di Medicina e Chirurgia, Seconda Università degli Studi di Napoli, Via Arena 4, 81100 Caserta, Italy.
giovanni.aliotta@unina2.it

**Abstract.** The authors discuss the figure of Federico Delpino (1833-1905), an outstanding Italian botanist of the XIX century, focusing on his cooperation with the major scientists of his time, among whom Charles Darwin. Moreover, they underline the crucial influence that Federico Delpino's scientific thought and innovative studies on floral biology and plant systematic had over the development of botanical sciences in the XIX century and on the birth of modern plant biology.

**Riassunto.** Gli autori presentano la figura di Federico Delpino (1833-1905), illustre esponente della botanica italiana dell'Ottocento, evidenziando i suoi rapporti scientifici con altre eminenti figure del suo tempo, tra cui Charles Darwin. Inoltre, evidenziano l'influenza che il pensiero scientifico e gli studi innovativi di Federico Delpino, rivolti specialmente alla biologia fiorale e alla sistematica vegetale, hanno avuto sullo sviluppo delle scienze botaniche nell'Ottocento e sulla nascita della moderna biologia vegetale.

**Key words**: Charles Darwin, Federico Delpino, History of biology, Plant biology, Pollination

## Introduction

History of biology is marked by the longevity of its issues and it commands respect because of the enormous diversity of life, in terms of space (all the continents), time (since 3,8 billions of years ago), dimension (ranging from viruses to whales) and habitat (air, soil, water). For centuries, biological phenomena have been classified in two main scientific disciplines: medicine and natural history, corresponding to modern natural sciences.

The Greeks had already praised harmony of nature and many of the current scientific issues (ex: embryology, systematic) were known to Aristotle, who stood as a point of reference until the scientific revolution of the XVI century. Since then, the western civilisation has been studying the rules of physics, but no other natural aspect was as reluctant to reveal its rules as diversity of organisms.

The XVIII century was the golden age of natural history, that was enriched by the historical voyages of James Cook, Louis Antoine de Bouganville and Philibert Commerson. Jean Jacques Rousseau's books and those by illuminist philosophers showed a renewed interest in nature. It was a century characterized by collections of plants, animals and minerals. Botany was still linked to medicine, thus European physicians-naturalists mainly searched for therapeutic properties of plants, particularly of those introduced after the great voyages of exploration. Naturalists also focused on classification of plants, following criteria that could facilitate their recognition (Mayr 1990).

The Swedish scientist Charles Linnaeus gave the most important contribution to this field. He proposed a new classification of plants, according to a logic division, based on the presence or absence of the flower and on its characteristics. Linnaeus developed his concept of species affirming that: we count as many species as the different shapes created by God. Then, as other scientists of his time, he thought that the number of living things had been established at the moment of Creation and their classification would reveal the divine pattern of creation.

There was a dispute in France about the validity of the Linnaean System that, having a rigid scheme and being based on floral characters, placed species in different classes, although they were similar, according to other characters (for example, a group such as gramineous plants was divided in seven classes). Moreover, observations made by relevant scientists of that period arose doubts about an immutable number of species. This debate involved scientists such as the French Georges Louis Buffon, Bernard de Jussieu and Jean Baptiste Lamarck, the Germans Joseph Gottlieb Kolreuter, Johann Wolfgang Goethe and Gottfried R. Treviranus, the English Joseph Banks, president of the London Royal Academic Society and the Italian Domenico Cirillo, physician and botanist at University of Naples, relevant personality of the Neapolitan Enlightment and president of the Legislative Commission for the Neapolitan Republic of 1799 (Aliotta & Aliotta 2001).

The botanist Treviranus and the botanist-zoologist Lamarck, independently from each other, introduced the term "biology" in two papers, both published in 1802. The first meant biology as philosophy of living nature, while the latter referred to a wider acception, beyond morphology and systematics, typical of natural history, rather concerning the study of functional processes of organisms with an holistic view of nature (Treviranus 1802-1822; Lamarck 1802) . In this scenario, at the beginning of XIX century, there were outstanding biological discoveries: the cellular theory, the origin of species, sexual reproduction of plants, hereditariness of characters.

Federico Delpino is the brightest figure of the Italian botany in the XIX century. The most innovative aspect of Delpino's scientific research is the institution of a new discipline, plant biology, that should collect and describe relations established among living things, among plants and between plants and animals, in order to understand functions such as reproduction, dissemination, survival and self defence (Borzì 1905; Catalano 1955).

Our aim is to introduce him with a brief biography, illustrating his activity in the scientific context of his time. In particular, we will consider the cultural references, the method he applied and his cultural heritage.

## Academic Biography

Federico Delpino was born on December 27, 1833 in Chiavari, in the outskirts of Genoa, Italy. He had a weak health and he was compelled by his mother, since early childhood, to spend most of the time outdoor, in a still existing small garden, that became the place of his early observations on swarms of ants and insects surrounding the flowers. After the High School at Chiavari, he attended the first Course of Mathematics at University of Genoa, but he quit after the first year.

Referring to his childhood and youth, in 1864 Delpino wrote a note on a botany textbook: "Studium vegetabilium puer meditabar inconscius, adolescens adgrediebar ardentissime. Sortes adversae me ad aliena rapuerunt." ("As a child, I unconsciously thought about studying plants. As a young man, I was deeply fascinated by it. Fate brought me to different things.").

After the disappointment for the experience at the University, his parents allowed him a long journey to the far east, where he collected plants, especially in the Dardanelli strait. When he got back, his honesty drove him to find a job, so that he could be economically independent from the family. He found a job at the custom office of the Ministry of Finance, in Turin. Despite his weaknesses, Delpino could find the time and the way to deepen his knowledge about literature and philosophy and to commit himself to the study of plants.

In 1865, when the capital city of the kingdom was transferred from Turin to Florence, Delpino, apart from his duties, could live in a place suitable to his ambitions; he got access to the resources of the Florence Botanical Garden and Botanical Museum; he could also read the books of the Webbian library. In 1867, professor Filippo Parlatore proposed Delpino as an adjunct professor, because he had appreciated his skills; so, Delpino officially started his career. Four years later, in 1871, he became professor of natural sciences at Vallombrosa

Royal Institute of Forestry, but he basically taught botany. While he was there, Delpino conceived the idea of a voyage around the world, so he boarded the warship "Garibaldi" as a naturalist. The ship had been set up for the educational voyage of the prince Tommaso di Savoia. Unfortunately, Delpino was forced to quit the circumnavigation because the ship lacked basic scientific equipment. He returned to homeland after visiting Brazil and collecting plants in the surroundings of Rio de Janeiro. At the end of 1875, after a concourse, Federico Delpino became full professor of botany at University of Genoa, where he continued his studies on floral biology and published a book about phyllotaxis (DELPINO 1883). In 1884, he moved to the University of Bologna and his fields of interest were myrmecophilous structures and systematics.

Ten years later, he moved to Naples where he continued researches about pollination, the key point in his scientific work, which defines the field of interest for plant biology. In 1899 he started the journal "Il Bollettino dell'Orto Botanico della Real Università di Napoli". In 1903, in occasion of his 70th birthday, the University and his colleagues tributed him honours and gave him a medal. While he was in Naples, Delpino became Dean of the Faculty of Science, "Accademico dei Lincei" and President of the Italian Society of Botany.

He died in Naples on May 14, 1905 and was buried in the cemetery of Poggioreale, in the famous people's yard.

## RESEARCHES (1865-1905)

Federico Delpino's scientific thought is testified by 492 papers and 90 of those represent the better known part of Delpino's production, which is about floral biology, systematic and defining plant biology. Other writings are fragmentary productions and concern all fields of botany (GEREMICCA 1908).

### *Floral biology*

Delpino gave relevant original contributions in this field, that were acknowledged in the international community, giving him a place of honour in the history of pollination, along with Camerarius, Koelreuter, Sprengel and Darwin. This history began in 1694, when the German botanist CAMERARIUS (1694) coined the term and showed that pollination of the stamen is necessary to the formation of seeds. Thus, stamen and pistils are "the sexual organs of the flower". These studies were not continued until 1761, when Koelreuter discovered the different types of pollination, underlining the role of insects and dichogamy, the floral structures and strategies that prevent self-pollination (KOELREUTER 1761).

In 1793, Konrad SPRENGEL, in his work "The secret taken from nature about structure and pollination of flowers", described accurately the pollination by insects and dichogamy, demonstrating the luring function of corolla, that floral structure favours cross-pollination in certain plants, and the mutual adaptation of the flowers and of their pollinators. His conclusion was: "…it seems that nature prevents flowers from self-pollination". Sprengel's results were ignored until 1862, when Charles DARWIN (1862) published "On various contrivances by which British and foreign orchids are fertilized by insects", explaining results not in the terms of Sprengel's teleological interpretation, but according to his theory on the origin of the species, published three years earlier (DARWIN 1859).

Inspired by the works of Sprengel and Darwin, Delpino, in the spring of 1865, made cross examinations on the mechanism of pollination in orchids and asclepiads. Experiments brought him to discover a type of pollination by insects that he describes in this way: "The aggregation of pollens in masses involves astonishing contrivances among Asclepiadeae, just like those Darwin reported about the orchids; indeed the masses of pollens produced by the stems are held in the trunk of imenotters (purple xylocopa), when they visit flowers to suck out nectar. Imenotters contribute to cross-pollination when they visit other flowers".

Delpino agrees with a famous Darwin's sentence: "No organism is self-pollinated forever", and he shows that cross-pollination, or dichogamy, is not prevented by hermaphroditism, because obstacles of different nature, such as a different ripening of pollens and eggs. In the course of evolution, hermaphrodite flowers followed rather than preceded unisexual ones, in order to arrange an economy of energies and materials; this could be considered as random, according to Darwin's theory, while Delpino considers it a natural design, occurring whenever difficult environmental conditions require a system different than eterogamy, such as autorganic reproduction.

Delpino (1868) reviewed observations by other botanists, collected from many textbooks of physiology, that represented the core of his scientific production. He classified and denominated different systems of pollen transportation, partly referring to an existing dictionary, partly upgrading it; Delpino established the definition of anemophilous and zoophilous plants, the latter divided into entomophila, ornitophila, malacophila.

At the same time, the way opened by Darwin and Delpino was followed by the most important naturalists of the time and it allowed Delpino to exchange information, comments and personal interpretations with the most influential German scientists, Fritz, Hermann, Muller, Friederich Hildebrand, and with Darwin himself. The latter gave most attention to works and criticism of the Italian botanist and was rather cautious in criticizing his teleological view. In the paper "The effects of cross and self fertilisation in the vegetable kingdom" (London 1876), Darwin reported references and results gathered by Delpino in "Ulteriori osservazioni sulla dicogamia", in particular those about anemophilous syndromes and floral nectars, while the most important European Schools focused their attention on Italian researchers (Alippi Cappelletti 1996; Pancaldi 1983, 1984).

It is worth mentioning Delpino's observations and interpretations of colours, scents and structures of flowers, that reveal the intriguing interactions between those and pollinating insects, giving new explanations. He found that the colour of flowers must be different than green, so that pollinating insects can quickly detect and visit flowers. Delpino made a very interesting biological classification of colours, by distributing them in four classes: ordinary, shining, metal and dark. Delpino did not limit himself to classifying or defining colours, he also determined their range of visibility and found that white is the most recognizable colour on a green background. White is followed by yellow, red, bright red, purple and light blue. He observed that the range of chromatic power in a meadow is different than the one found in a wheat field in bloom or in a bare field with ashy or yellowish colours, because, in this case, the grades of red are predominant and are followed by light red, purple, light blue, white and yellow. He also noticed plants with yellow flowers were usually able to overcome those with white flowers, elevating the stamen further and by growing bigger flowers. Then, a peculiar phenomenon occurs; if one looks at a meadow from up above, from the top of a tower for example, he mostly sees white flowers; instead, while observing from the height of a man, species with yellow flowers are in clear majority.

It is interesting to report what Delpino says about the blossoming of ivy, because it testifies his insect knowledge also: "In the exact time of vining, ivy is in bloom. If some creeper covers up walls with a luxurious vegetation, one can explain such an abundant and "mellifera" blossoming, that provides an extraordinary show, from morning to evening and for many days, luring an astonishing number of insects. There are bees and other insects. They are pollinating insects of second line. Many wasps are also lured, to catch other insects rather than collecting nectar. Blossoms are also an exclusive benefit for diptera and silfidi." Also: "Many years ago, at my house in Chiavari, I stood by a wall covered up with ivy and for many days, from dawn to dusk, I stared at the fascinating show of its blossoming. I wanted to deepen my knowledge about genera and species of silfidi; I collected so many samples, that I achieved my goals beyond any expectation. The most abundant and recklessly active pollinating insect was *Helophilus florens*, followed by *Erystalis tenax*, then by genera such as *Chrysotoxum*, *Volucella*, *Syrphus*, *Paragus*, *Callicera* and *Eumerus*." (Geremicca 1908).

Moreover, Delpino did not miss to notice the succession of two or more colours within the same flower and, with clever observations, he determined that a change of colour indicated the right time for pollinating insects to visit the flower.

Once established the value of chromatic function, he clarified the luring function of coloured parts in the flowers, in order to perform dichogamy. For example, it is worth mentioning the acute interpretation of the dark purple colour taken by flowers of wild carrot (*Daucus carota* L.) in the middle section, called umbrella. That colour, detaching itself from white of inflorescences, is useful to make the umbrella of carrots easily recognizable for the bees and to divert them from other white ombrelliferes (Delpino 1865).

Delpino also defined 45 types of floral scents, with direct observations, and distributed them in five classes (of which a translation is here attempted): delicate, aromatic, carpological, smelly, and nauseous

These scents act in three different ways: apatic, luring pollinating insects in general; sympathetic, attracting special kinds of pollinating insects, and non-sympathetic ones, keeping away small insects, unable to perform cross-pollination. Flower scent lures insects more than colours do, and some bees and lepidopterists provide evidence for this, visiting flowers that release scent only at night.

Scents and colours lure pollinating insects to flowers with an attracting function enabled. Delpino detects eleven types of lure and, among those, nectar, lymph and edible pollen represent the most important sources of nourishment (Geremicca 1908).

He supports Aristotle's theory about the behaviour of bees while visiting flowers; it affirms that bees only visit one kind of flower during each trip. In this way, bees save time and labour during their visits, because flowers of different species deal with different species of insects; thus, it is easier and more effective for the bee to visit one species at time. Delpino gave a finalistic explanation to this phenomenon: "The mutual adaptation among flowers and their pollinators reveals, with logical evidence, the existence of a preconscious and intelligent principle concurring in the development of organisms".

*The importance of floral biology in classification*

As years went by, Delpino started to think about a complete reform of the classification of plants, according to biological criteria, philogenetic method and morphology. Delpino considered this method as "non plus ultra" of perfection, because all the methods used since then followed morphological criteria only, resulting to be weak and insufficient. As an expression and application of these new principles, Delpino published, between 1888 and 1894, a collection of lectures entitled "Applicazione di nuovi criteri per la classificazione delle piante". They were outstanding from any point of view, specially for the clever findings in the field of systematic botany (Delpino 1888-1897). Among those, it is relevant the lecture read on March 19, 1889 at Academy of Sciences of the University of Bologna, where he underlined: "Systematic botanists make a serious mistake by associating Taxaceae with the genus *Ginkgo*, when the latter differs from both Taxaceae and Conifers". This exclusion and the institution of a new family, Ginkgoacaceae, stood as a memorable decision in history of taxonomy (Savelli 1965).

Botanical geography also became an issue of great importance to Delpino, always under the influence of biological investigation; associated with Morphology and Paleonthology, it concurs to the foundation of history of evolution in the Plant Kingdom and it is the ultimate achievement of his botanical studies. These exact concepts inspired the following papers: "Studi di geografia botanica secondo un nuovo indirizzo"; "Rapporto fra la evoluzione e la distribuzione geografica delle Ranuncolacee" e "Comparazione biologica di due flore estreme, artica ed antartica" (Delpino 1898, 1899b, 1900).

Delpino, considering triple pentacyclic floral architecture of many monocotyledon plants as the result of a long evolution, assigns to them the value of archetypical and prototypical. He also thought that monocot plants, having a structure that he called policyclic, to distinguish it from triple pentacyclic, derived from forms of dicot plants: "If one thinks that

Ranuncolaceae, Ninfaceae, Botumaceae, Idrocarideae and Alismaceae are fresh water plants, it is confirmed the hypothesis that the division between dicotyledon and monocotyledon plants took place in flooded fields, in ancient geological ages when the proportion between emerged lands and flooded lands was different than today".

Among the classifications of that period, the one formulated by Engler in 1892 was the closest to his own, for biological and philogenetical aspects; this classification considered two types of monocot plants: those with a variable number of floral cycles and organs within single cycles, and those with trimerous and pentacyclic flowers. However, Delpino underlined all the weak points of this theory, that concerned the distribution of families in classes and showed that his monophyletic scheme was closer to the truth than the one proposed by Engler. He concluded: "We both started from the same phylogenetic and biological principles; it shows that we applied a different explanation (and application) of those principles. Further observations and considerations would probably tell which theory is closest to the truth." (GEREMICCA 1908; DELPINO 1898, 1899b).

*Definition and limits of plant biology*

This field represents the most important legacy of Delpino's scientific thought, and it is worth to make a summary of what he wrote in Naples in 1899 on the first issue of the "Bulletin of the Botanic Garden" (DELPINO 1899a):

"In 1867 it was proposed the institution of a new branch of phitology, destined to investigate vital functions of plants; for that discipline, I suggested the name of Plant Biology" (Pensieri sulla biologia vegetale, etc.; vol. XXV del "Nuovo Cimento", Pisa, 1867); "Material for observations was not abundant, consisting mainly of Crist. Corr. Sprengel's work entitled"Stealing a secret from nature: the structure and fertilization of flowers", published in 1793, the Issue released by C. Darwin on "Apparecchi della fecondazione nelle orchidee nostrane (sic!) ed esotiche" and other few memories published by C. Darwin himself, Hildebrand's writings and my own; all those works concerned about a single branch of biology: floral biology. Although the relative unavailability of that material (one hundred times that amount, today) we had, since then, a quite adequate understanding to define a new scientific field; it shows in the following passages, that are worth mentioning because the book I quoted is hard to find: "…phitologists in their issues on botany, could not detect phenomena related to external vital functions of plants; they neglected them, or associated them to phenomena of internal life (p. 4)".

"Plants find endless source of nourishment in the elements of soil and air; for being air a mobile element in itself, it was thought that, because plants could not get to nourishment, it would get to plants".

"Another important need is getting away from its foes. Nature…provided outstanding remedies…by releasing bitter, disgusting and poisonous juices or stingy smells that make them respected and avoided by the majority of animals." And about cross-fertilisation, he adds : "most of the flowers are traps with different and wonderful mechanisms, that give the role of pollinators to insects, unconsciously dedicating themselves to the work of transporting pollens from one flower to another".

"…And about the biological role of dissemination and distribution of plants, it seems to succeed with a better rate among plants rather than animals, that are even able to move. The vital principle controls weather agents and imposes dissemination to the winds; it converts stamen of some clematidi, anemoni, driadi, etc. in feathery pappus. When calyx of singenesie and of some valerians, surrounding the seeds of cotton, of apocinee, asclepiadee and epilobi of poplars with soft hair…".

"…reviewing those phenomena of biological origin, I tried to define the limits of biology and of the materials it is made of. "…Morphology must be subordinated to biology. Without the support of biology, what is morphology if not a mere and sterile contemplation of shapes and metamorphosis, that lacks of concepts, meanings and spirit? What is simple morphology if not a measure of our ignorance? But, if both disciplines support each other, they represent an interesting scientific compound. So, human mind can elevate itself to the understanding of concepts that have been developing during the evolution of vegetal organisms. According to this point of view, biology, considered as a separate branch of natural sciences, finds its own way and fulfils its special mission. Being detached from physiology, that concerns internal life, biology develops within a different field."

The passages reported above show our view of biology back in 1867. Three main types of biological phenomena were already considered; those about protecting the organism, those about cross fertilization and finally those about dissemination. Later on, there were more papers about biological aspects. This scientific field grew considerably.

"Fourteen years later, in 1881, I got back to the matter; after reviewing recent published papers, I proposed about limits and contents of plant biology; this is what we did with an article entitled "Basics of Plant Biology; prolegomenon". This work was meant to be a treatise of plant biology, that classifies all the known biological phenomena according to their functions.

"Defining the field of plant biology was easy; as long as we don't start from the position stated in the prolegomenon."

"It is better to consider each single organism or individual, no matter if unicellular or made of millions of cells, a three-dimensional being as mathematician would call it, as it expands in three dimensions, a solid body indeed. Because of its own nature, it needs a centre and a periphery, with central organs or parts and peripheral organs or parts. From the geometrical point of view, this is very much true; after reflection, it is also true from an organic point of view, even though the organic centre rarely corresponds to the geometrical centre. As life applies to both central and peripheral organs, it follows that, although life should be considered as a unique thing, we should consider two types of life, an internal or central one and an external or peripheral one. The first case is covered by physiology, a term accepted by all the scholars. The proposed term biology might cover the second case."

"I tend to agree with these concepts. I think that two new terms should have been coined: endobiology instead of physiology and exobiology instead of biology. This is opposed by the fact that the term physiology has been used for centuries by medical and naturalist schools."

"As we have to use the term physiology, although it has a conventional value, we should give a conventional value to the term biology too, and use it as an abbreviation of exobiology."

"Warming and many others have used the term ecology lately…"

"I should criticize Warming for replacing the term biology with ecology lately. I really don't like this word. In 1881, I analysed the use of this word in my "Prolegomenon to Biology" and I rejected it. I don't even like this term when it applies to exobiology of human beings "who build up roofs and houses, while thinking of economic rules". It might be said that this term is backed up by Haeckel's authority (1886). He just mentions that in a very brief footnote on page eight of his Generelle Morphologie der Organismen. Let's quote this along with the literature that legitimated the use of the term biology; as long as naturalists don't realize that organisms are three dimensional beings, therefore they have a centre and a periphery, thus a central life and a peripheral life. Only then, we will rationally adopt the terms endobiology and exobiology, banning physiology and biology from the scientific dictionary."

Although most of Delpino's plant biology is included in ecology now, his researches on pollination haven't lost their appeal. The extraordinary variety of relationships between flowers and their visitors demand the attention of ecologists even today, and leads to new findings (FAEGRI & VAN DER PIJL 1979; PACINI 1988).

Delpino's scientific thought is part of the so called "Biocomplexity", a term that scientists recently coined to conceptualise the vast variety of relations occurring among organisms and between these and the environment. Its field of interest is wider than that of ecology; it is about mutual relations among soil, bacteria, plants, herbivores, carnivores, geological and climatic factors (TAYLOR & HAILA 2001; COLWELL 2001).

About the criticism that Delpino received from fellow scientists because none of his works was supported by observations at the microscopy, it is proper to state, as Catalano did (CATALANO 1955), that back to the days when Delpino defined the basis of his Plant Biology, these basis were provided by evidence that could be observed "directly" with the naked eye. Indeed, the debate on the "scientific methodology" in biology is still open and scholars of "philosophy of ecology" and biocomplexity agree that both experimental method and observative-comparative methods are relevant.

Both methods are about collecting data and observation plays a key role.

As Shopenhauer stated, a creative mind is able "to think about something that no one had thought of, by looking at something everyone can see" (MAYR 1990). Imagination, then, is the most important prerequisite to "scientific progress".

## LITERATURE CITED


ALIOTTA G., ALIOTTA A. 2001. Domenico Cirillo, medico e botanico dell'Illuminismo italiano. Il Policlinico, Sez. Prat. 108: 181-187.

ALIPPI CAPPELLETTI M. 1996. Federico Delpino, memorie di biologia vegetale. Giunti Gruppo Editoriale, Firenze.

BORZÌ A. 1905. Federico Delpino, discorso commemorativo. Nuovo Giorn. Bot. Ital., n.s. 22: 417 – 439.

CAMERARIUS R.J. 1694. De sexu plantarum epistola. Tubingen Akademischer.

CATALANO G. 1955. La biologia vegetale del nostro tempo (Ricordando Federico Delpino nel 50° anniversario della morte). Delpinoa VIII: 1 – 31.

COLWELL R.R. 2001. Biocomplexity. Encyclopedia of Life Sciences. Macmillan Publishers Ltd, Nature Publishing Group. www.els.net.

DARWIN C. 1859. On the origin of species by means of natural selection on the preservation of favored races in the struggle for life. Murray, London.

DARWIN C. 1862. On the various contrivances by which British and foreign Orchids are fertilised by insects. Murray, London.

DELPINO F. 1865. Relazione sull'apparecchio della fecondazione nelle Asclepiadee. Aggiuntevi alcune considerazioni sulle cause finali e sulla teoria di Carlo Darwin. Gazzetta Medica, s. II, 15, pp. 372-374, 382-384. 390-391. 398-400.

DELPINO F. 1868. Ulteriori osservazioni e considerazioni sulla Dicogamia nel Regno Vegetale. Atti della Soc. Ital. di Sc. Natur. Milano. 1868, 11 pp. 265-352; 1869, 12 pp. 21-141, e 179-235; 1873, 14, pp. 151-349; 1874, 17, pp. 266-407.

DELPINO F. 1883. Teoria generale della fillotassi. Atti d. R. Univ. Di Genova, 4: 1-345.

DELPINO F. 1888-1897. Applicazione di nuovi criteri per la classificazione delle piante. Mem. R. Acc. Sc. Bologna. I, s. IV, 9, 1888, pp. 221-243; II s. IV, 10, 1889, pp. 43-73; III, ivi, pp. 565-599; IV, s. V, 1, 1890, pp. 253-278; V, s. V, 3, 1892, pp. 217-244; VI, s. V, 6, 1896-97, pp. 83-116.

DELPINO F. 1898. Studi di geografia botanica secondo un nuovo indirizzo. Mem. d. R. Acc. Scienze, Bologna, s. 7: 329-358.

DELPINO F. 1899a. Definizioni e limiti della biologia vegetale. Bollettino dell'Orto Botanico della Regia Università di Napoli, 1: 5-23.

DELPINO F. 1899b. Rapporti tra l'evoluzione e la distribuzione geografica delle Ranuncolacee. Mem. d. R. Acc. Scienze, Bologna, s. V, 8: 17-66.

DELPINO F. 1900. Comparazione biologica di due flore estreme, artica ed antartica. Mem. d. R. Acc. Scienze, Bologna, s. V, 8: 527-564.

FAEGRI K., VAN DER PIJL L. 1979. Principles of pollination ecology. Oxford Press.

GEREMICCA M. 1908. L'opera botanica di Federico Delpino esposta criticamente.

Bollettino della Società dei Naturalisti in Napoli. XXI: 8-200.

KOELREUTER G. 1761. Vorlaufige Nechrichte von einigen das Geschlecht der Pflanzen betreffenden Versuchen und Beobachtungen. Leipzig.

LAMARCK J.B. 1802. Recherches sur l'organisation des corps vivants. Paris.

MAYR E. 1990. Storia del Pensiero Biologico. Ed. Bollati-Boringhieri, Torino.

PACINI E. 1988. Biologia della riproduzione, 100 anni di ricerche botaniche in Italia. In: F. Pedrotti (Ed.). Centenario della Società Botanica Italiana. pp. 345-354. Milano.

PANCALDI G. 1983. Darwin in Italia. Ed. CLUEB, Bologna.

PANCALDI G. 1984. Teleologia e Darwinismo, la corrispondenza tra C. Darwin e F. Delpino. Ed. CLUEB, Bologna.

SAVELLI R. 1965. L'orto botanico di Bologna. In: Giacomini V., Merola A. (Eds). Orti Botanici delle Università Italiane. Biblioteca dell'Orto Botanico di Napoli.

SPRENGEL C.K. 1793. Das entdeckte Geheimniss der Natur, im Bau und in der Befruchtung der Blumen. Berlin.

TAYLOR P.J., HAILA Y. 2001. Philosophy of ecology. Encyclopedia of Life Sciences. Macmillan Publishers Ltd, Nature Publishing Group. www.els.net.

TREVIRANUS G.R. 1802-1822. Biologie oder Philosophie der Lebenden Natur fur Natur-forscher und Aertze. voll. 6, Gottinga.