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Review: Women in plant disease management

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Women first began to take a stance in science over 50 years ago, and since then, they have produced a great number of publications. However, the first step towards science was a matter of accrediting women as rightful members of the scientific community. During the late nineteenth and early twentieth centuries, women started to enter into graduate programmes, and such a step helped them to make a difference. In many cases and many countries, botanists and mycologists were, in some way, pioneering in the plant pathology discipline. This manuscript considers some of the women who led the way in plant pathology, with a special focus on those who also dealt with the early aspects of plant disease management. Women who were active in different geographical areas are featured, and an attempt has also been made to provide some less well-known stories. Moreover, the importance of women behind the scenes, as is the case for many lab and field technicians, whose lives have not been chronicled, is acknowledged. Finally, some suggestions are given on how to improve the present situation and increase the number of women in science as well as in technical positions, with special emphasis on the positive effect of female mentors and role models.

KEYWORDS

leadership, model, mentoring, history, science

1 Introduction

Why, in 2022, are we still discussing women in plant disease management or even in other disciplines? Probably because the gender issue, although less critical than before, has not yet been completely resolved. Although this topic has been tackled seriously in several places, countries, and situations, it is still a matter of concern. This issue concerns industrialised and developing countries and women of all working ages, across all disciplines, with some very unfortunate examples of faculty gender imbalance, particularly in the case of hard sciences. It is not necessary to be a feminist to notice an often unfair and counter-productive gender imbalance in many workplaces.

It is well known that women began to take a stance in science over 50 years ago and that they have produced a vast number of publications over the years. The first step towards science was therefore a matter of accrediting women as rightful members of the scientific community. For many years, some agricultural disciplines (i.e., botany, floriculture, etc.) have been considered more suitable for women than others. Moreover, for a long time, women have been considered more suited to taking care of "details". As a consequence, in the past, they were mostly employed in technical positions, to mount specimens, take care of the lab,

etc. In the worse cases, they were tasked with only washing glassware and preparing coffee, and it took a long time for them to obtain more interesting jobs. Finally, during the late nineteenth and early twentieth centuries, women started to enter into graduate programmes, a step that helped them to make a difference.

In a way, women botanists and mycologists have long been pioneering in plant pathology in many countries. Many female mycologists, who studied and illustrated mushrooms in the field, often worked on their own, in isolation, and much of their work remained unpublished. Since the topic of women in plant pathology has already been covered by Ristaino (2008) and in other specific publications (Vidaver, 1987), this short review focuses on only some of the women that led the way in different geographical areas and attempts to tell some less well-known stories, focusing on those who dealt with plant disease management, a topic that has been explored much less than plant pathology. Moreover, the importance of women behind the scenes, such as many lab and field technicians, whose lives have not been chronicled, will be underlined.

2 Leading the way: Examples from the past

Certain women in the USA led the way, one such woman being Flora Waumbaugh Patterson, who was born in Ohio in 1847. She started studying fungi as a childhood hobby and, after marriage, spent years taking care of her family while working towards an A.M. degree, which she completed in 1883. After she found out that Yale did not accept female students, she enrolled in Radcliffe College (Cambridge) to continue her studies in Botany. Patterson started her career with the USDA when she was 48 years old and in her 27 years of service, she contributed to the science of plant pathology (Rossman, 2002), which was still young at the time. Patterson was indeed a pioneer, not only as a non-traditional student, pursuing her career despite heavy family commitments (her husband had been disabled in a steamboat explosion), but also understanding the need to inspect imported agricultural commodities. From 1906, she was involved in a plant inspection programme that permitted many previously unknown fungal diseases to be detected. For instance, she intercepted *Synchytrium endobioticum*, the causal agent of potato wart, which remains a major problem requiring quarantine. Patterson was also involved in the controversial rejection of a set of cherry trees from Japan due to the presence of pathogens. Her experience in the devastating effects of newly introduced pathogens was instrumental in the passage of the Plant Quarantine Act in the USA in 1912, which gave the Animal and Plant Health Inspection Service (APHIS) the authority to regulate the importation and interstate movement of nursery stocks and other plants that could carry pests and diseases that are harmful to agriculture. Patterson was indeed a pioneer in the field of biosecurity (Palm, 1999; Ristaino, 2008).

Another interesting story is that of Effie Southworth, born in North Collins, New York (USA), in 1860. After a B.S. in 1985, she worked as an instructor in Botany and later (1887) as an assistant mycologist for USDA, thus becoming the first female researcher in plant pathology to have been hired by the USDA. In 1892, she moved on to the position of Assistant in Botany with Barnard College in New York. She resigned after marrying the head of the Department and then worked as her husband's assistant. After her husband's death in 1918, Southworth moved to the University of Southern California, where she became a member of the botany faculty. In 1922, at 62 years of age, Southworth received a Master of Science degree in Botany, continued to serve as Professor, and was named Honorary Curator of the Herbarium in 1938. Her last records were added to the Herbarium in early 1947, shortly before her death, at the age of 87. Of special interest is the fact that, during her work as an assistant mycologist, she dealt with the diagnosis of and recommendation of plant disease management for a diverse range of diseases in economically important crops, such as apple scab (Galloway and Southworth, 1889).

Cynthia Westcott, born in 1898 in Massachusetts (USA), truly deserves the name "plant doctor". Her family owned two farms, and this surely influenced her childhood and her interest in plants as well as her practical attitude. At Cornell, she was the only woman in a department of 40 men. In such a context, she was assigned the jobs that were typically assigned to women in those days: preparing microscope slides for plant pathology courses, preserving specimens, etc. This experience helped her to become an excellent plant diagnostician, thus helping her to become a plant doctor. Wescott was a pioneer in engagement and communication, as she was extremely good at communicating her professional knowledge to the public at large. Her ability to entertain was as strong in teaching as it was in socializing: on Rose Day, Westcott opened her gardens to the public to display her test plots and let visitors admire her blooming roses. The number of guests who attended surpassed 700 (Horst, 1984). She was a skilled writer and even became a well-known author for popular magazines (Westcott, 1952): exactly what we now call public engagement, 80 years ahead of its time!

Helen Hart, born in 1900 in Wisconsin (USA), was defined by her colleagues as "an extraordinary woman". Hart studied wheat stem rust (Hart, 1929) and significantly contributed to increasing our knowledge of pathogen specialisation and cultivar resistance. She also pioneered the use of controlled environments to study the effect of environmental factors on the interactions between the host and the pathogen. In addition to glasshouse experiments, Hart's research programme also included field studies. In order to evaluate the resistance of wheat germ plasm to stem rust, she worked with breeders at USDA, where she also coordinated monitoring programmes to trace stem rust outbreaks in the field. Hart became president of the American Phytopathological Society in 1955 (Gegenhuber, 2006), quite an achievement for a woman in those days, although it might be said that she had deserved it much earlier. Eventually, in 1965, she became a Fellow of the American Association for the Advancement of Science and of the American Phytopathological Society.

At this time, things were also moving in Europe. Mary Dilys Glynne, born in 1885 in North Wales (UK), was the first woman plant pathologist hired by Rothamsted (Hertfordshire), where she contributed to the control of potato wart disease by improving the detection methods of potato cultivars that were resistant to the pathogen. Glynne's method for screening resistance to potato wart permitted breeders to shorten the duration of their tests (Glynne, 1926). Her long-term work on the take-all decline, including the management of the disease through cultural methods, was also of interest and pioneering (Glynne, 1951). Glynne reported that the incidence of take-all increased until the sixth consecutive wheat crop

after fallow, and then decreased. Later, many researchers around the world studied this phenomenon, investigating the biological mechanisms on the basis of her results.

Margaret (Claire) Shephard, born in 1931 in Maidenhead, Berkshire (UK), studied plant pathology at the Imperial College of Science and Technology and entered Imperial Chemical Industries in 1954. She was a pioneer in pesticide development, a field in which she held many patents and developed many new fungicides. In the early 1980s, she discovered, among others, two systemic fungicides, dimethirimol and ethirimol, and she also understood the risk of the development of resistance, due to their specific mechanism of action (Shephard et al., 1975). Shephard also transformed untried compounds into practical, effective fungicides and developed techniques for handling many plants and plant diseases in glasshouses as well as miniature tests that enabled chemicals to be tested in the laboratory or controlled environment rooms. Throughout her career, she developed many other agricultural speciality chemicals and also recognised the side effects of triazole fungicides, using them for plant growth retardation. Shephard also served as Treasurer of the International Society for Plant Pathology (1993-1998).

Johanna Westerdijk, born in 1883 in Amsterdam (The Netherlands), is known as the Grand Lady of Dutch Plant Pathology (Boonekamp et al., 2019). In 1917, she became the first woman to be appointed as a university professor in the country; she contributed to a great extent to the development of plant pathology in the Netherlands and throughout the world, working on both basic and applied research. She was also very much involved in engagement, where she sometimes had to deal with the unfriendly behaviour of growers. She was often insulted since the presence of a woman was an unusual event in the field. On one occasion, a bulb grower threw a handful of soil into her face. Her practical research included disease control and breeding for resistance, where she showed a special interest in trees. Westerdijk was also a pioneer in travelling abroad, with long stays in Indonesia, then a Dutch colony, Japan, and the United States. She paved the way, in the US, for many of her Dutch students (Kerling et al., 1986). Westerdijk had very good organisation skills; in fact, she developed the fungal culture collection of the CBS (CBS-KNAW Fungal Biodiversity Centre or Centraalbureau voor Schimmelcultures - Central Bureau of Fungal Cultures) into the largest fungal collection in the world (Kollmer, 2022), a centre which now has outstanding visibility. In 2017, to commemorate her 100th anniversary and to celebrate her legacy, the CBS was renamed after her as the Westerdijk Fungal Biodiversity Institute.

Antje Kaars Sijpestein, born in 1919 in Bloemendaal, (the Netherlands), was very active at TNO (Netherlands Organisation for Applied Scientific Research) in Utrecht, where she worked as a chemist on the mode of action of many fungicides. Her activity spanned from the first groups of fungicides developed after World War II, such as dithiocarbamates in the 1950s, to the new classes of systemic fungicides. In 1960-1970, she was very active in studying the biochemical mode of action (Kaars Sijpesteijn, 1970) as well as the mechanisms of resistance that started to develop in fungal pathogens against fungicides with the specific mode of action. Her research has been extremely useful in optimising the use of fungicides, thanks to a better knowledge of their activity, thereby contributing to the development of modern plant disease control.

Mathilde Bensaude, born in 1890 in Portugal, was well known for her studies on many fungal pathogens and was also interested in developing control methods for many pathogens (Bensaude and Keitt, 1928) and pests. She was crucial in establishing the Plant Quarantine Services at the Ministry of Agriculture in Lisbon and during her service there, Bensaude implemented a series of regulations that soon became essential in establishing good sanitation methods for many crops. Bensaude took part in many international activities, even helping to establish the Coffee rust centre in Oeiras, in order to maintain the populations and strains of *Hemileia vastatrix* in coffee plants, in a country where coffee is not grown.

Maria de Lourdes Vieira Borges, born in 1916 in Portugal, conducted important studies on plant virology, mostly working with electron microscopy and dealing with viruses that affect vegetable, ornamental, and industrial crops. In the late 1960s, she extended her interest to other fields, and in her later years, she pioneered the use of soil solarisation as a soil disinfestation method in Portugal (Borges and Sequeira, 1996).

In Italy, Giuliana Luigia Evelina Mameli, who was better known as Eva Mameli Calvino, was a true pioneer in scientific disciplines. Born in 1886 in Sassari, she graduated in Natural Sciences at the University of Pavia, where, in 1915, she became "libera docente", the equivalent of professor, in Botany, thus becoming the first woman to obtain such a degree in such a discipline (Figure 1). Together with her husband (Mario Calvino), she spent a period in Cuba, where they funded an agricultural school and an Experimental Station that worked on sugarcane. Back in Italy, in 1925, they founded the Experimental Station on Floriculture in Sanremo, which was headed by Mario Calvino. She was the head of the Botanical Garden at the University of Cagliari, from 1926 to 1929, then she moved back to Sanremo, where she worked at the Experimental Station of Floriculture, of which she became Director in 1947, after the death of her husband (Figure 2). Her research spanned from botany to plant physiology, from mycology to plant pathology (Mameli Calvino and Pollacci, 1910). Her work on the diseases of ornamental plants, including carnations, an important flower crop on the Italian Riviera, is of particular interest. Eva Mameli Calvino was very active at the Botany Laboratory of Sanremo in supporting flower growers with the diagnosis of many diseases in different crops and also providing advice on their control (Mameli Calvino, 1935). She remained extremely active right up until her death in 1978, in Sanremo. She also founded, together with her husband, the Italian Society of Flower Friends and the "Il giardino fiorito" journal. Eva Mameli Calvino represents an incredible example of a woman in science, open to the world, able to explore different fields, and able, even in the early 1900s, to establish a very open and completely equal work relationship with her husband. Incidentally, Mameli Calvino was also the mother of the famous Italian writer Italo Calvino. Eva Mameli Calvino was even proposed as a role model for young girls in a book written by Accati (2011).

Jole Ceruti Scurti, born in Torino (Italy) in 1922, earned a degree in Natural Sciences at the University of Torino, where she began her career as a specialist in mycology in the phytosanitary services of the Ministry of Agriculture. This early period of work, besides giving her a solid knowledge of mycology, also taught her a practical approach and a concrete attitude to solving practical problems that she would later exploit at The University of Torino, where she taught mycology.

FIGURE 1
Portrait of Eva Mameli Calvino (courtesy of the Biblioteca Civica of Sanremo, Italy).

Apart from her more classical studies in mycology, where she demonstrated special interest in the role of soil fungi in the humification process, Scurti also investigated the biology and epidemiology of several plant pathogens, such as wheat smut, *Condrostereum purpureum*, the causal agent of the silver leaf of fruit crops, and the Fusarium wilt of gladiolus (Ceruti-Scurti, 1959) (Figure 3). Scurti was also active in the field of plant disease management. Her pioneering work in the 1960s on mycotoxins is of great interest. Scurti fully understood the role of mycotoxins in food and feed safety (Ceruti Scurti and Cantini, 1965). Scurti's scientific career was interrupted by her untimely death in 1981, just after being appointed full professor in Plant Pathology (Figure 4).

Ethel Irene McLennan, born in 1891 in Williamston, Victoria (Australia), was the first Doctor of Science to be appointed in mycological research in Australia (1921) and the fourth woman to graduate in the Faculty of Science. She spent a period at the Rothamsted Agricultural experimental station in Hertfordshire and London's Imperial College of Science and Technology, working on soil-dwelling fungi and the physiology of host-parasite relationships. Back in Melbourne, McLennan taught plant pathology and mycology (Parbery, 1989) and worked on diseases found in flowers, fruit, trees, and timber. She also interacted with the CSIRO Forest Commission in Victoria. Through her leading role at the University, she became a role model and was known as "Dr Mac". After retirement, she took charge of the University Herbarium.

Gretna Margaret Weste (Parkin), born in 1917 in Gretna (Australia), graduated in Science and investigated wood-rotting fungi and timber treatments. Despite her work and expertise in wood decay, she was classified as a "temporary typist" and was obliged to interrupt her work when she got married. After about twenty years devoted to motherhood, with occasional periods of school teaching, Gretna Weste returned to the Botany School, where she taught mycology and plant pathology. Thus, Weste was finally able to return to research on root rot caused by *Phytophthora cinnamomi*, a field in which she became the foremost authority on this pathogen in Australia (Nessy, 2000). She advised government agencies, participated in conservation and in

FIGURE 2
Eva Mameli Calvino at work (Courtesy of the Biblioteca Civica of Sanremo, Italy).

FIGURE 3
Jole Ceruti Scurti presenting her work at a phytopathological Congress in 1960.

botanical and plant pathology societies and conferences, and she continued to work and publish on this pathogen and supervise research until shortly before her death in 2006.

3 Women behind the scenes

The history of plant pathology and plant disease management is full of talented women who never dared surpass their positions of technicians, thereby spending their entire professional life behind the scenes, in their labs. Although their stories have not been chronicled, they worked hard in the past and continue to do so nowadays. Their work was, and still is, extremely important, but has rarely been fully recognized. Most research relies on the hard work of extremely skilled technicians, and in the past, most of them were women and still are today. In many cases, women, despite obtaining brilliant results in their studies, do not undertake or complete postgraduate programmes and frequently enter academia at low levels or in casual or temporary positions. Women often only participate in post-graduate programmes on a part-time basis and, therefore, cannot fully focus on research. All this prevents them from reaching the critical mass needed to pursue a scientific career. The importance of the role played by women in plant clinics, particularly in many southern countries, should also be mentioned. Plant clinics are meeting places (mostly operating from local markets, community centres, and cooperatives) where farmers can take samples of their diseased crops to trained plant health extension officers for free diagnosis and recommendations on how to manage the problem (Boa, 2009; Majuga et al., 2018). Thanks to their services, farmers likely lose fewer of their crops to pests and diseases, and this results in improved crop quality and yield, leading to higher farm incomes, and, ultimately, less food insecurity and poverty. Plant clinics have been functioning since 2003, and over 4000 of them have been established in 34 countries across Africa, Asia, and the Americas (Boa, 2009). A survey carried out by the Center for Agriculture and Bioscience International (CABI) Plantwise Programme shows that the attendance of women at plant clinics is low compared to the proportion of women employed in agriculture (Terefe, 2020). Again, in the case of plant clinics, the presence of more female extension workers or plant doctors, by attracting and engaging more women among farmers seeking advice, could greatly improve their impact on food security, thereby reducing gender asymmetry in information and increasing initiatives that do not only target males (Silvestri et al., 2019).

FIGURE 4
Jole Ceruti Scurti in her garden.

4 How to move forward

For many years, it has been clear that women have had to work harder than men and earn more degrees to attain even comparatively meagre advancements. In the past, women were often given a corner in a student lab, while men of equal rank had private offices. Moreover, women also suffered salary inequities. However, in the past few years, the general situation has improved a great deal. Although gender inequality in the scientific sector remains a central concern, the number of women in plant pathology and plant disease management has been steadily increasing, and this number is now close to 40% at the early career stage. For example, at the University of Torino, the number of female students involved in agricultural studies is currently around 40% (compared with 20% in the mid-1970s), and the same can be observed for PhD students. In a survey carried out in Europe in 2016, women accounted for 47% of PhD students, 37% of associate professors, and 21% of full professors (European Commission, 2016). Similar patterns have been reported in the United States, but gender imbalance is even higher in Japan (Bagues et al., 2017). In 2022, in the US, only 18.2% of plant pathologists at large (not only involved in research) were females (https://www.zippia.com/plant-pathologist-jobs/demographics/). Women in research still face multiple challenges in advancing their careers; being under-represented at the mid-levels, women are not able to achieve a critical mass in senior academia and, even today, only a limited number of

women are able to reach the highest (i.e., full professorship) and leadership positions. There is still a glass ceiling that is difficult to break. Women also tend to be less mobile than men and this lack of mobility may hinder their progression in their careers. In Europe, the recent research support programme called "Next generation funds" is taking proactive steps towards imposing that 40% of all new positions be allocated to the less represented gender. Besides proactive steps, such as the establishment of gender quotas, it is probably even more important to establish and nurture a research culture. Female scientists probably do not pursue academic careers just because they are not encouraged to do so. Female role models can have a positive impact on the scientific careers of women. Short workshops, with good interaction with speakers, could be very useful in providing practical examples and helping young female scientists to envision themselves as faculty members (Handelsman et al., 2022). Moreover, good mentors also play an important role, since they can provide women, in the early stages of their careers, with support, encouragement, and practical advice, thereby helping them to build confidence and motivation and to achieve critical thinking. Most of the recommendations made by Vidaver (1987) are still extremely valuable and applicable to both men and women.

5 Conclusions

Throughout the centuries, and against all odds, often only counting on their own strength and resilience, women have overcome professional and societal barriers to advancing science. In the 19th century, some women, in male-dominated scientific fields, were able to break down barriers and stereotypes.

This paper is not intended to be a comprehensive history of all the women who have contributed to plant disease management. It instead aims to stimulate and inspire young women to envision or revise their professional goals and to pursue a variety of approaches to reach such goals. Stories from the past, in fact, provide examples of commitment, persistence, resilience, etc. Many of the women from the past described here had good mentors or sponsors - often older colleagues - who were capable of understanding their attitudes and helping them develop their careers. This can be done by helping female students to better orient their research in the early stages or, sometimes, by just being encouraging and supporting their choices. Since practically no female role models were present when most of the women discussed in this paper began their careers, role models did not play a major role for them. However, it is now believed that role models help in the recruitment of more women to scientific fields. This has been observed, for instance, in agronomy (Rosenzweig, 2000).

Women continue to have a great disadvantage in certain fields, especially those associated with more prestige and better pay (Bello and Sarrico, 2020). Furthermore, the gender gap in research is likely to increase as a result of the COVID-19 pandemic. A recent Organization for Economic Cooperation and Development (OECD) survey has shown that women are increasingly experiencing a reduction in the time they can dedicate to research and are more concerned than men about job security and career opportunities (Bello and Galindo-Rueda, 2020). Fair selection processes are necessary and, unfortunately, too often, it happens that women do not help other women (sad but true)!. A recent study carried out in Italy and Spain, using information on 100,000 applications for associate and full professorship positions, showed that a larger number of women on evaluation committees did not lead to an increase in the quantity or quality of the selected female candidates. Information from individual voting reports suggests that female evaluators are not significantly more favourable towards female candidates. The same survey indicates that male evaluators become less favourable towards female candidates when there are females on the committee (Bagues et al., 2017). The ADVANCE Institutional Transformation Programme, funded by the National Science Foundation, suggests several interventions that can be introduced to train search committees in good search methods and to sensitise them to unconscious bias related to gender, race, and disability (Handelsman et al., 2022).

A gender balance is important in any workplace and is crucial for the scientific community as a whole, as well as for our profession, in plant disease management.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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