Journal of Plant Pathology
https://doi.org/10.1007/s42161-024-01644-w

REVIEW

Teaching plant pathology: a forty-five year long journey

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Received: 27 October 2023 / Accepted: 13 April 2024

Abstract
This paper describes the experience of teaching plant pathology in Italy and traces the teaching environment over a period of more than 45 years, split into three main periods: 1975–2000; 2001–2020; and after 2020. The three periods are marked by different attitudes towards agriculture and, consequently, by a variable attractiveness of agricultural study programmes for students, as well as significant changes in the population of teachers and students. The teaching experience has been described by focusing on the changes that have taken place, from the perspectives of both students and teachers, all considered in an environment of continuous transformation. The changing importance of agriculture, the different approaches of people (consumers) towards agriculture, and how it has influenced students' choices are considered. Data related to student enrolment at the College of Agriculture of the University of Turin have been used to provide real figures, which are useful to obtain a better understanding of the changes in the student population, also considering the different attractiveness of Agricultural Sciences, Forestry and Food Science, as well as the variations in the composition of the female student population, which increased from 28% in the late 1970's to 38% in 2020. Female students now show the highest interest in Food Science Courses. The changes in the students and teachers' backgrounds and attitudes, as well as in the teaching and learning methods are considered, and some critical considerations are drawn, also on the basis of the developed personal experience. Moreover, the effects of the Covid-19 pandemic disruption are discussed.

Keywords Teachers · Students · Agriculture · Innovation · Digitalisation

Setting the stage

Plant pathology is a truly multidisciplinary science, which has sprung up from botany and plant physiology, with close links to a very diverse array of individual subject areas, including agriculture, horticulture, microbiology, mycology, bacteriology, virology, soil science, biochemistry, molecular biology, genetics, and even more. The discipline ranges from molecular aspects to field practices and requires a broad range of perspectives and approaches, both in research and in teaching (Richter et al. 2018). Teaching plant pathology is becoming more and more challenging, since the discipline has expanded over the years to incorporate new interdisciplinary approaches, including artificial intelligence and social sciences, as well as a rapidly increasing number of research methods.

The experience of the author in teaching plant pathology for over forty years is considered in the context of the Italian situation, but also considering some influence from abroad. Indeed, several periods spent in leading Universities in the Netherlands and in the United States of America provided good opportunities for the author to confront with other teaching models. Other papers have dealt with teaching and innovation in teaching (Schuman 2003; Eastburn and D'Arcy 2009), while MacDonald et al. (2009) provided a thorough analysis of the status and challenges of teaching plant pathology in the United States of America. The challenges and opportunities of plant pathology foundation and graduate education in the United States (Richter et al. 2018), India (Chattopadhyay 2021) and worldwide (Fletcher et al. 2020) have recently been considered. This paper describes the teaching environment over a period of more than 45 years, split into three main periods: 1975–2000; 2001–2020; and after 2020, periods into which my teaching journey at the University of Turin falls. As will be discussed, the three periods mark different attitudes towards agriculture and, consequently, a variable attractiveness of

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Published online: 29 April 2024

agricultural study programmes for students, as well as significant changes in the population of teachers and students. The teaching experience is described by focusing on the changes from the students and teachers' perspectives, which are considered in an environment that is undergoing continuous transformation. What have the driving forces of these changes been? The changing importance of agriculture, the different approaches of people (consumers) towards agriculture, and how it has influenced students' choices are all considered. Data related to student enrolment at the University of Turin have been used to provide real figures, which are useful to obtain a better understanding of the changes that have been taken.

The changing environment in three different periods (1975–2000; 2001–2020; after 2020)

The attitude towards agriculture

Despite an urgent need to feed an increasing population, for many of the years in the last decades of the XX Century there was a limited perception of the role of agriculture amongst the general public, which was closely connected to a poor understanding of this productive sector as well as of the science in general (Table 1). Unfortunately, too many people still think that food comes from the grocery store, and there is a lack of literacy of the general public or, even worse, of many policy-makers concerning agriculture. In 1993, Schumann stated, with reference to the United States, that urban and suburban populations did not have the scientific background to participate, as citizens, in decisions related to their own health, land use, an appropriate use of genetic resources, a rational judgement of genetic engineering, and the risks linked to the use of pesticides (Schuman 2003). Thirty years after such a consideration, unfortunately, the situation has not improved much, not only in the United States but also in most industrialised countries. While food, cooking, restaurants, and well-known "chefs" attract increasing interest, the food production system, which is based on agriculture, is still neglected and poorly understood as an economic activity. Despite such a poor understanding of agriculture, many changes have been observed during the past few decades: issues related to environmental protection and food safety have become more relevant. Very recently, the Covid-19 pandemic and the Ukraine war have generated much more attention towards agriculture as food supply. During Covid-19, people began to understand that if agricultural production were to stop, this would have affected not only growers but also all of the general public. Most of what we eat comes directly, or after processing, from the fields. The war in Ukraine has added to such an understanding of the threat of food insecurity, even in industrialised countries. These two factors have affected the perception of agriculture among the general public to a great extent (Table 1).

In the meantime, different needs of the stakeholders have emerged and, unfortunately, only a few Agricultural departments and colleges around the world have been able to keep up the pace, that is, to quickly adapt the content of their programmes and courses, in order to make them more suitable for industry and societal needs. In my opinion, this is particularly true in Italy, where a complex bureaucracy, coupled with low flexibility by teachers, has complicated rapid changes in developing new teaching programmes as well as in reshaping (or shutting down) obsolete ones, when needed.

Programmes in agriculture

In Italy, until the 1988/1989 academic year, the Programme in Agricultural Sciences (and later in Forestry) lasted 4 years and corresponded to MS programmes in the US and British systems. In 1988/89, the Programme became 5-years long. In 2010, a more similar system to the US one, with two levels (3 years for BS and 2 years for MS) was introduced.

Table 1 Changes observed in the agricultural environment in the three different periods

Aspect considered	Period (years)		
	1975–2000	2000–2020	After 2020
Agricultural profile of the public	Little considerations of productive agriculture	Romantic vision of agriculture (slow food attitude)	After Covid-19 and the Ukraine war, the economic role of agriculture has become better understood
Agricultural profile of policy makers	Poor understanding	Poor understanding. Often seen as the origin of environmental pollution.	A small increase in consideration. Risk of food insecurity.
Topics that generate debate	Pesticides; genetically modified crops	Genetically modified crops; pesticides	Genetically modified crops; cultured meat; husbandry as the source of emissions; meat consumption
Attractiveness to students	Low	Increased, particularly in the field of Forestry and Food Science	Decreased number of students but increased consciousness of the social role of agriculture
Attractiveness to families (of students)	Low	Moderate	Increasing

For many years, in the late seventies and throughout the eighties, relatively small numbers of undergraduate students were attracted to sciences in general: as a consequence, an even smaller number of them were attracted to agricultural sciences. At the University of Turin, a relatively small number enrolled in Agricultural Science, which, lasting 4 years, was the only *Curriculum* offered until the early eighties. Table 2 refers to the 1975–1979 period: until 1978, the number of students enrolled in Agricultural Sciences was quite low. The number of students started to increase in the late seventies, with 19 to 32% of the students being female (Table 2). Before the 1980s, half of them were from secondary technical schools and the other half from classical or scientific high schools (Lyceum) (data not shown). In the early eighties, when University enrollment in Italy was open to all types of colleges and to students from all types of secondary schools, the number of students in Agriculture increased. At the University of Turin, such an innovation also corresponded with the opening, in the 1980/81 Academic Year, of the Programme in Forestry (renamed Environmental Forestry Science ten years later, in 1990/91), which attracted, year by year, an increasing number of students (Tables 3 and 4). The percentage of female students in Agricultural Sciences remained around 25% until the end of the eighties, and was slightly lower in Forestry (Table 3). The rapid increase in the number of enrollments in the Forestry *Curriculum* soon led to practical problems, due to insufficient infrastructures and a limited number of jobs in such a sector. Starting from 1992, the number of students enrolling in the Forestry Programme surpassed that of Agricultural Sciences (Table 4). The percentage of women enrolled only increased slightly, starting from 95/96, in both Programmes, reaching 39% in the in 98/99 (Table 4). In the first two Academic Years of the 2000's, enrolment was quite high, in part thanks to the success of the Forestry course, but it then started to decrease, mainly due to the introduction, in 2007/2008, of a "controlled" number of enrolments in Forestry. In that year, a maximum of 75 students could enrol in the first year. This number was doubled in 2014/2015. Such a measure permitted the Forestry Programme to be managed better, that is, according to the available infrastructures and jobs. The percentage of women remained in a range of 31 to 37%, with, in general, a slightly higher percentage enrolling in Forestry (Tables 5 and 6). The Forestry *Curriculum* attracted not only more women but also, in general, more students from Lyceum (data not shown). A relevant change took place in the 1990s, when a Programme in Food Technology was opened, and it started to bloom in the mid 1990's, attracting many students, and with a higher percent of females, higher than 45% (Tables 5, 6, 7). In the meantime, in the 2000–2010 period, Agricultural Sciences was split into several *curricula*, dealing with horticulture, agricultural engineering, animal science, organic agriculture, with relatively small numbers of students enrolled in each one (data not shown). The Biotechnology *Curriculum* was developed in the late 1990s, with a closed number of students right from the beginning, and it has remained stable throughout the years. Moreover, in 2010, the National University reform introduced two levels: BS and MS. Such changes led to a fragmentation of the Agriculture Programme and a proliferation of C*urricula*; some of which, in part due to the limited enrolment of students, lasted only for short periods (data not shown). Many of the Programmes that started at the BS level dealt with practical topics.

In the 2010–2020 period, the number of students in Forestry decreased, while the number enrolling in Food Technology increased, and only the closed number of enrolments to the first year, introduced at the beginning, permitted the figures to be kept constant (Table 6).

The Covid-19 and post-Covid periods signalled the start of a continuous decrease in the number of enrolled students, in all the offered *Curricula* (Table 7).

Teaching and teachers

Teaching

Until 1990, plant pathology was taught as the main course (plant pathology) in Agricultural Sciences, together with two other subjects, physiological plant pathology and plant disease management, which were generally selected by most students. Other courses, such as diseases of ornamentals, of vegetables, pesticides, were offered as optional courses. When the Forestry Programme started, forest pathology was taught to all the students and Wood diseases was offered as an optional course. Later on, in 2000, plant pathology, including plant disease management, remained as the only mandatory course for students in Agricultural science. Plant pathology was taught in the Food Technology

Table 2 Students enrolled at the Faculty of Agriculture of the University of Turin, from 1975 to 1979

Curriculum	Academic year					
		75/76	76/77	77/78	78/79	79/80
Agricultural sciences	Male	21	28	43	65	96
	Female	5	12	20	26	27
Total		**26**	**40**	**63**	**91**	**134**
%Female		**19.2%**	**30.0%**	**31.7%**	**28.6%**	**27.6%**

Table 3 Students enrolled at the Faculty of Agriculture of the University of Turin in Agricultural Sciences and Forestry, from 1980 to 1990

Curriculum	Academic year											
		80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91
Agricultural science	Male	355	449	498	574	566	583	578	533	535	516	483
	Female	116	136	163	200	218	212	199	187	177	170	170
Total		**471**	**585**	**661**	**774**	**784**	**795**	**777**	**720**	**712**	**686**	**653**
Female (%)		**24.6%**	**23.2%**	**24.6%**	**25.8%**	**27.8%**	**26.6%**	**25.6%**	**26.0%**	**24.8%**	**24.7%**	**26.0%**
Forestry	Male	104	198	233	275	310	316	282	284	324	329	367
	Female	26	43	53	85	88	92	90	91	88	105	132
Total		**130**	**241**	**286**	**360**	**398**	**408**	**372**	**375**	**412**	**434**	**499**
%Female		**20%**	**17.8%**	**18.5%**	**23.6%**	**22.1%**	**22.5%**	**24.1%**	**24.3%**	**21.3%**	**24.2%**	**26.4%**
Grand total		**601**	**826**	**947**	**1134**	**1182**	**1203**	**1149**	**1095**	**1124**	**1120**	**1152**
%Female		**23.6%**	**21.7%**	**22.8%**	**25.1%**	**25.9%**	**25.3%**	**25.1%**	**25.4%**	**23.6%**	**24.5%**	**26.2%**

Programme, albeit with a limited number of credits, focusing on post-harvest diseases and aspects related to storage and processing, such as the presence of contaminants (pesticide residues, mycotoxins). The more specific courses in the field of plant pathology decreased in Italy as they did worldwide. Special courses, with hands-on practice, almost disappeared, as did the upper-level specialty ones. Some topics, particularly in the field of applied agriculture, were at risk, both in teaching and in research.

At a certain point, in the late eighties, plant pathology lost visibility worldwide as a discipline, in part due to the disappearance of many plant pathology stand-alone departments. In the nineties of the past century and early 2000, our discipline, being included in larger multidisciplinary departments, often had problems finding its own space and role. Such an invisibility impacted our profession in many ways: students were less attracted, public funds were not directed to plant pathology (Gadoury et al. 2009). As a result of the shrinking students enrolments, a loss in courses, degrees, and faculty members was observed in many places. By often becoming a minority in larger departments, it sometimes became difficult for members of the group to influence policies, *curricula* development, or faculty positions to any great extent. For many years, very little innovation was observed in the teaching methods, with most classes being given in the traditional lecture and lab manner, with lectures providing the bulk of content knowledge and labs providing the practical aspects and the opportunity for interaction and skill development. The lab component of the course has always been critical and crucial for student learning and for success in the final test. Lab classes require additional resources, in terms of materials, facilities, and instructors. As a result of the increase in the number of students, in the late 1990s-early 2000s, it has become a challenge to maintain such courses, mostly because of the lack of facilities but also, albeit to a lesser extent, of resources for teaching material. Despite these constraints, plant pathology teachers continue to value the lab components of their courses and strive to maintain a minimum hands-on experience for students.

In 2020, the Covid-10 pandemic was particularly disruptive. Teachers had to adapt, very quickly, to distance teaching. The lockdown started in 2020, exactly at the beginning of the spring semester. In just a few days, teachers were asked to record their lessons, which, at first, were provided to students on the University teaching platform, together with slides and teaching material. After a few months, at the beginning of the 2020/2021 Academic year, lessons were provided on-line, following a normal schedule, and were also recorded. This way of teaching permitted a better contact with the students to be established. Lesson by lesson, teachers and students learned to interact. Digital tools proved very useful to make teaching more interesting,

Table 4 Students enrolled at the Faculty of Agriculture of the University of Turin in Agricultural Science, Forestry and Food Technology from 1990 to 2000

Curriculum		Academic year								
		91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00
Agricultural science	Male	458	443	501	536	496	428	433	407	418
	Female	164	157	174	236	233	222	223	237	238
Total		**622**	**600**	**675**	**772**	**729**	**650**	**656**	**644**	**656**
%Female		**26.3%**	**26.2%**	**25.8%**	**30.6%**	**32%**	**34.1%**	**34.0%**	**36.8%**	**36.3%**
Forestry	Male	410	476	597	769	777	543	562	597	590
	Female	169	227	275	374	411	313	337	386	390
Total		**579**	**703**	**872**	**1143**	**1188**	**856**	**899**	**983**	**980**
%Female		**29.2%**	**32.3%**	**31.5%**	**32.7%**	**34.6%**	**36.6%**	**37.5%**	**39.3%**	**39.8%**
Food Technology	Male		24	28	42	58	81	117	197	268
	Female		2	4	11	16	12	45	93	125
Total			**26**	**32**	**53**	**74**	**93**	**162**	**290**	**393**
%Female			**7.7%**	**12.5%**	**20.7%**	**21.6%**	**12.9%**	**27.8%**	**32.0%**	**31.8%**
Grand total		**1201**	**1329**	**1579**	**1968**	**1991**	**1599**	**1717**	**1917**	**2029**
%Female		**27.7%**	**29%**	**28.7%**	**31.5%**	**33.2%**	**34.2%**	**35.2%**	**37.3%**	**37.1%**

Table 5 Students enrolled at the Faculty of Agriculture of the University of Turin in Agricultural Sciences, Forestry and Food Technology from 2001 to 2010

Curriculum		Academic year									
		00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10
Agricultural science	Male	440	444	343	331	334	305	294	257	238	273
	Female	242	250	168	120	90	81	79	74	65	94
Total		**682**	**694**	**511**	**451**	**424**	**386**	**373**	**331**	**303**	**367**
%Female		**35.5%**	**36%**	**32.9%**	**26.6%**	**21.2%**	**21.0%**	**21.2%**	**22.4%**	**21.4%**	**25.6%**
Forestry science[a]	Male	608	606	462	428	398	334	286	240	216	251
	Female	385	366	294	272	235	188	171	137	124	128
Total		**993**	**972**	**756**	**700**	**633**	**522**	**457**	**377**	**340**	**379**
%Female		**38.7%**	**37.6%**	**38.9%**	**38.8%**	**37.1%**	**36.0%**	**37.4%**	**36.3%**	**36.5%**	**33.8%**
Food Technology	Male	189	330	335	344	362	342	331	340	322	324
	Female	93	144	153	149	171	183	175	186	192	187
Total		**282**	**474**	**488**	**493**	**533**	**525**	**506**	**526**	**514**	**511**
%Female		**33.0%**	**30.4%**	**31.3%**	**30.2%**	**32.0%**	**34.8%**	**34.6%**	**35.3%**	**37.3%**	**36.6%**
Grand total		**1957**	**2140**	**1755**	**1644**	**1590**	**1433**	**1336**	**1234**	**1157**	**1257**
%Female		**36.8%**	**35.5%**	**35.0%**	**33.0%**	**31.2%**	**31.5%**	**31.8%**	**32.2%**	**32.9%**	**32.5%**

[a]Which became Environmental and Forestry Science in the 1990/1991 academic year

Table 6 Students enrolled at the Faculty of Agriculture of the University of Turin in Agricultural production, Environmental and Forestry Science and Food Technology from 2011 to 2020

Curriculum		Academic year									
		2010/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20
Agricultural production	Male	181	318	379	438	411	474	511	524	526	517
	Female	125	151	168	232	203	231	232	237	239	239
Total		**306**	**469**	**547**	**641**	**614**	**677**	**743**	**761**	**765**	**756**
%Female		**40.8%**	**32.2%**	**30.7%**	**36.2%**	**33.1%**	**34.1%**	**31.2%**	**31.1%**	**31.2%**	**31.6%**
Environmental and Forestry Sciences	Male	278	263	242	263	263	226	217	212	209	186
	Female	133	111	116	151	125	117	112	105	100	93
Total		**411**	**374**	**358**	**414**	**388**	**343**	**329**	**317**	**309**	**279**
%Female		**32.4%**	**29.7%**	**32.4%**	**36.5%**	**32.2%**	**34.1%**	**34.0%**	**33.1%**	**32.4%**	**33.3%**
Food Technology	Male	351	371	454	531	523	620	571	555	523	516
	Female	224	285	422	563	531	579	519	501	482	443
Total		**575**	**656**	**876**	**1094**	**1054**	**1199**	**1090**	**1056**	**1005**	**959**
%Female		**39.0%**	**43.5%**	**48.2%**	**51.5%**	**50.4%**	**48.3%**	**47.6%**	**47.4%**	**48.0%**	**46.2%**
Grand total		**1292**	**1499**	**1781**	**2149**	**2056**	**2219**	**2162**	**2134**	**2079**	**1994**
%Female		**37.3%**	**36.5%**	**39.6%**	**44%**	**41.8%**	**41.8%**	**40.0%**	**39.5%**	**39.5%**	**38.9%**

Table 7 Students enrolled at the Faculty of Agriculture of the University of Turin in Agricultural Production, Environmental and Forestry Sciences and Food Technology from 2021 to 2023

Curriculum		Academic year			
		20/21	21/22	22/23	23/24[a]
Agricultural production	Male	532	451	413	
	Female	225	203	187	
Total		**757**	**654**	**600**	**124**
%Female		**29.7%**	**31.0%**	**31.2%**	
Environmental and Forestry Sciences	Male	188	184	175	
	Female	98	93	79	
Total		**286**	**277**	**254**	**99[b]**
%Female		**34.3%**	**33.6%**	**31.1%**	
Food Technology	Male	453	407	384	
	Female	371	356	338	
Total		**824**	**763**	**722**	**153**
%Female		**45%**	**46.6%**	**46.8%**	
Grand total		**1867**	**1694**	**1576**	**376**
%Female		**37.2%**	**38.5%**	**38.3%**	

[a]Data still provisional at the time of submission (October 25, 2023)

[b]The figure is the sum of the enrolment in Environmental and Forestry Science and Mountain Science, a new *Curriculum* starting in 2023/24

and the material provided by the larger Scientific Societies (American Phytopathological Society *in primis*) was extremely useful, particularly in helping to organise practical lessons at a distance.

Podcasts and short films, sometimes prepared by the students themselves, were used. Such tools will continue to be used in the future. Indeed, they are some of the few positive leftovers of the Covid-19 pandemic.

Teachers

During the considered period, teachers also changed, as shown under Table 8. In the late seventies-early eighties, most teachers had a sound agricultural background and a deep knowledge of agriculture. Such aspects influenced their teaching, which was always conducted paying attention to the practical aspects of agriculture. During the past 10–15 years, faculty members with field research interest have retired in many Universities without being replaced, due to economic constraints. When they were replaced, in most cases, they were replaced by a new more lab-oriented faculty member, with a background in biology or biotechnology, and often with limited knowledge of agriculture. Such teachers are often not related to growers and have little or no interest in applied or field research, being more interested in molecular biology. This fact, in conjunction with fewer grants for applied research, does not permit the crucial topics of applied plant pathology to be fully exploited. Such a situation, which has been clearly described by MacDonald et al. (2009) and Gadoury et al. (2009) for the United States, has also expanded very rapidly to other countries, including Italy. No one has yet examined whether the effect of the lack of faculties in the traditional areas is having a negative impact on student recruitment and, even more so, on teaching. However, such an aspect is surely generally considered negatively by enterprises and, in general, by stakeholders.

Faculties with a background in other disciplines may differ in their expectations and emphases, with regards to introductory coursework. This can create gaps in fundamental knowledge and skills among students whose only formal education in plant pathology is through the introductory course offered at the undergraduate level. No data are available to determine the extent to which these differences do in fact exist, and, if they do, how they impact student preparedness for the work force (Richter et al. 2018). It should also be mentioned that today, in our field, even in the most competitive systems, it is difficult to attract, recruit, and retain the best teachers, who are generally attracted by other fields of research. Therefore, very often, we are not able to attract first choice teachers from other disciplines.

Table 8 Changes observed in the teacher populations throughout the years in the three different periods

Aspect considered	Period (years)		
	1975–2000	2000–2020	After 2020
Background	Good expertise in agricultural sciences	Increasing number of teachers from biology, biotechnology,…	Increasing number of teachers from biology, biotechnology,…
Experience	Before teaching full courses, teachers gained expertise by teaching practical lessons	Starting, from the assistant-professorship period, teaching full courses. Less time to devote to research.	Starting, from the assistant-professorship period, teaching full courses.
Expertise in agriculture	Generally good	Often limited	Often very limited
Knowledge of English	Limited to a few	Generally limited	Improved. Even now few courses are taught in English
Teaching material	Classical: books, teachers' lecture notes	Books, with the increasing use of slides and the Internet	Books, slides, and internet material
Attitude towards new technologies	Very limited	Limited	Improved
Interaction with students	Formal, and easier with low numbers of students	Becoming less formal, but complicated by the high numbers of students	Informal

Another interesting aspect is related to the age and experience of teachers. Until the late nineties, it was customary for researchers to gain expertise in teaching by assisting older professors in the lab part of their courses. Moreover, in general, young teachers were assigned to more specialised courses (i.e., for graduate students), while older teachers taught undergraduate students. Most teachers used to make their lecture notes available to students. This, with very few exceptions, no longer happens and mostly teachers simply provide slides. Recently, at least in Italy, due to a proliferation of Programmes with few students, young researchers, who are often highly specialised but with a limited agricultural background, have been immediately assigned to teach. In my opinion, supported by many curricula evaluation, this is having a negative impact on their productivity in research and also on the quality of teaching.

One negative aspect, at least in Italy, is the poor attitude to providing Programmes in English, thus limiting the attractiveness of courses to foreign students. In the late XX Centuries, unfortunately, many teachers did not have the English proficiency level needed to teach in such a language. The situation has now improved, but the few Programmes provided in English are still not so attractive. Unfortunately, too often, at least at the University of Torino in the field of agriculture, Programmes are designed in English by Italian teachers who teach Italian students in English, as they are not able to attract foreign students either at the undergraduate level or at the MS level.

Learning and students

Learning

Throughout the considered period, the learning process changed. In the late seventies-early eighties of the past century, a relevant part of the courses was provided as practical classes, with hands-on experiments, in part due to the limited number of enrolled students. The practical part of a course is often the only opportunity that students have to develop hands-on skills associated with the knowledge of the course content. Several studies have shown that hands-on activities help students increase their gains in knowledge over passive learning across many STEM subjects (Glasson 1989; Hake 1998; Grober et al. 2004). Freeman et al. (2014) showed that students in traditional lecture classes are 1.5 times more likely to fail than students who take active learning classes. The lecture notes provided by teachers, together with the available books, were useful tools in the learning process. At the end of the course, lectures, practical classes, and field visits provided students with a very good and complete arsenal. Plant pathology books, which were suggested to students at the beginning of the course, were considered useful and were used by most students. In the past 15 years, the availability of more advanced facilities, such as digital platforms and equipment, has permitted a broader use of slides and digital tools. Such a situation, which is positive from a certain point of view (i.e., in the case of working students), has reduced the attendance in class of students as well as the use of traditional books. My personal experience shows that the effect on the final results of the examination is not always positive.

Students

The decreased enrolment of students in agriculture has been accompanied by a decline in the student numbers as well as in interest in plant pathology. As a consequence, the numbers of qualified applicants for graduate school are in general declining. The brain drain that is affecting Italy often starts at the MS level, when the brightest students, after a BS in Italy, go abroad and stay abroad for their Ph.D, where they often also find better paid work.

In the 48 years considered here, the interest of students in agriculture has changed as has their characteristics, as shown in Table 9. The attractiveness of agriculture was low in the late seventies-eighties and early nineties, when it was very difficult to attract the brightest students. Interest increased in the mid-nineties, particularly in the case of Forestry, a *curriculum* that attracted bright students due to its environmental aspect. The change in its name from Forestry to Environmental and Forestry Science in the academic year 1990/1991 further increased its attractiveness, particularly among students who had a romantic idea of agriculture.

Throughout the years, students have become more diversified in terms of background studies in secondary schools. Although students in the seventies-eighties were used to resorting to books as their study material, starting in the nineties, they now prefer to use slides and internet material. Their knowledge of the English language has improved recently, as well as their digital attitude. An increasing number of certified learning disabilities has been observed throughout the years, particularly after the Covid-19 pandemics.

The Covid-19 disruption and the new challenges

The years 2020 and 2021 were mostly influenced by the Covid-19 pandemic, which produced a disruption in all teaching systems. Already back in the early 2000s, the Internet permitted much faster access to information and images for both students and instructors and resulted very useful

Table 9 Changes observed in the student populations throughout the years in the three different periods

Aspect considered	Period (years)		
	1975–2000	2000–2020	After 2020
Number	Small, particularly until the early eighties. Numbers increased in the 1990's with the opening of Forestry courses	Very high, with many students enrolling in forestry	Decreasing
Background	Half from technical schools and the other half from Lyceum until 1980. Later, more from technical schools. Often good knowledge of agriculture.	From all types of secondary school. Very often with no background in agriculture. Often with a strong attraction to nature.	All types. Very often with no background in agriculture.
Knowledge of English	Generally poor	Generally limited	Improved
Learning disabilities	Few declared	Increasing after 2010.	More frequent after Covid-19
Type of classes	Relatively small at the beginning. Increasing in the last few years.	Large. Over 100 students/class	Large. Over 100 students/class
Learning material	Books, lecture notes provided by teachers	Fewer books, more slides	No books (except for a very few exceptions)
Practical activities	Many: in the lab and in the field	Greatly reduced, due to the high numbers of students	Very limited
Interaction with teachers	Good, formal and respectful	Becoming less formal	Easy and very (too) informal

for life-long programmes designed for extension services (Vincelli 2009). Instructional technology, which provided interesting tools for classroom presentations and communications with students (Schuman 2003), became crucial during the pandemics, permitting students confined to home to be reached, thus making distance teaching and learning the normal status. During such a period, teachers had to adapt very quickly to a very different methodology of teaching as well as to the use of new tools, while students had to adapt to learning a very practical discipline, such as plant pathology, through distance learning. This was not an easy task, for either of the teachers or the students. With distance teaching as the only possibility, teachers had to improve their skills, to try and make their classes more interesting, to provide good material online, and to foster interaction with their students. Students lost the possibility of interacting with each other in the classroom and found new ways of distance interaction. The real challenge was teaching (and learning) the practical part of the course. This is where teachers and students gave their best, finding the best way to interact. A very interesting experience is that described by Suffert and Suffert (2022), who developed, during the International Year of Plant Health, in 2020, "phytopathological strolls" to observe symptoms on diseased plants in gardens, streets, and in open spaces, and shared this matter with a broad public. The lockdown created an additional motivation to improve the method, that is, of drawing up a real game, which proved useful to promote a favourable perception of plant pathology among the public. Students helped teachers to grasp the degree of their engagement, which is not an easy task with online teaching. From my own personal experience, I noticed that after just a few weeks of adaptation, despite the physical distance, the interaction with the students became very close, since we all understood that we were doing our best to survive. During those long months, I experienced a very high emotional engagement with my students. For our students, the diagnosis of plant diseases is one of the most difficult skills to develop (Yadav and Beckerman 2009). In traditional teaching, case studies on plant disease diagnosis help students to develop critical thinking and to engage them. This was even clearer with distance teaching: students, by proposing practical cases, became actors in the practical classes, using terraces, gardens, and/or orchards as labs to share with their fellow students. Fortunately, we were also able to adopt tools that had been developed to support diagnostics for distance education (Galea 2006) as well as the teaching material developed by certain scientific societies, such as the American Phytopathological Society.

Looking ahead: the main challenges

What has been described above shows that, after years of slow changes, things have moved very rapidly in the past few years, due to the speed of innovation, digitalisation and, finally, to the disruption caused by the Covid-10 pandemic. Such a situation leaves space for several challenges, which are considered briefly below.

There is still much to be done to improve student recruitment, such as trying to make plant pathology more attractive to young people. The brightest students should be involved in attracting new students, to provide them with real-world examples. Topics such as forensics, food safety, food security, saving forests and wild plants, environment protection, and biosecurity are particularly relevant today and suitable for attracting young people to our profession. Field and lab work could help attract more students. It will also be important to invest in summer outreach programmes for students. To do so, plant pathology programmes should indeed invest more funds on such activities, also by considering their impact on the enrolment of bright students, An increased movement of international students (North-South and South-North) would help increase enrolments: agricultural studies are still relevant in developing countries.

There is a clear disconnection between what the University teaches and what employers need. Teaching programmes, in order to remain relevant for the agro-food industry, need to place more emphasis on management, and on interpersonal and technical skills (Gisi 2009). Students need to be more adaptable to future changes. Critical thinking is important to help students to adapt to new challenges and opportunities. We teachers need to avoid clonal propagation of ourselves. In this respect, industry could help Universities by offering more internships for students and also by providing seminars. On-farm experience should be reintroduced for students. Students should be encouraged to attend local professional meetings in order to interact with potential employers. Moreover, there should be an increase in Ph.D. and post-doc students in applied areas. Teaching methods and tools should be renewed more frequently than was generally done in the past. The shifts caused by the Covid-19 years of brick-and-mortar students to digital students accelerated a trend that had already been developing. The digital experiences developed during the pandemic should not be abandoned. However, innovative teaching strategies do not always mean introducing the latest and greatest technology into the classroom, in order to improve student engagement and learning. Innovative teaching is the process of proactively introducing new teaching strategies and methods into the classroom. Peer teaching, assigning pathogens/diseases to groups of students provides students with the opportunity to independently conduct research on the topic and develop a presentation on it. With peer teaching, students learn such skills as independent study and presentation skills, and they gain confidence. Peer teaching can be coupled with flipped classrooms, where students complete their course work through peer-to-peer collaboration. Teachers should not be at the centre of a course, and instead should address personalised help and direction to students and student groups, as they complete their work. Peer teaching can include the jigsaw method, with students divided into groups and given different pieces of information. Introducing new skills and abilities, such as communication, critical thinking, writing, and international experience, is also important. Blended learning combines physical and online learning experiences that offer students more control over the time, place, path, and pace of instruction. It provides traditional classroom experiences as well as online tools and learning opportunities. Technology is a key component of blended learning. The flexibility of blended learning enables students to have more control over their learning methods. They can watch online lectures at home and engage in peer groups for collaborative activities. Distance education permits access to educational resources to be equalised, promotes self-learning, and helps working students (Black et al. 2019).

There is a need of funding to support experiential training as well as of grant programmes in applied sciences. Internships with industry and governmental agencies could also help. Moreover, closer ties with industry could influence and help colleges to maintain the basic agricultural disciplines (Gisi 2009).

There is a need for a new brand image: the public should understand that farmers are not the enemies of the earth, and, on the contrary, that life on earth depends on plants. There is a need to collect and share data related to the percentage of employed graduates, salaries, placement, etc. Such data should reach those people who have influence. We also need influencers in our field.

Conclusions

Plant pathology is connected to relevant social and economic issues: environmental protection and conservation, food safety and security, climate change and globalisation. Yet, it is continuously challenged to maintain its identity and reaffirm its existence according to the needs of those who grow food and fibre. As the ever-increasing world population requires more food to consume, it is necessary to respond with improved disease management methods that are less destructive for the environment. As stated by J.C. Walker many years ago, it is important that we encourage and help our students to keep “one foot in the furrow” (Mathre 2002). The Covid-19 pandemic helped plant pathology to be fully considered as an important component of circular health. For these reasons, plant pathology remains a critical topic, and teaching plant pathology, because of its complexity, remains a major challenge for both teachers and students. Gisi (2009) clearly exemplified the need to integrate knowledge on molecular biology, genetics, biochemistry, physiology, and epidemiology of the most important pathogens with applied aspects derived from agronomic questions in the teaching of plant pathology. Strong teams of excellence working on crops and/or problems, and more attention to those scientists that are capable of working across disciplines should be developed. It will also be very useful to introduce more industry perspectives into teaching, as well as contributions from research institutes, the government, extensions, botanical gardens,… Investing in life-long courses should be another priority, together with investments in critical infrastructures (farms, labs,…).

It is increasingly important to introduce plant pathology and the social role of diseases into an early *curriculum*, also into Sciences and Environment Colleges. Reaching new audiences should be a priority. Introducing plant pathology into biology and microbiology courses can help to enrich the education of the students in these courses, by introducing new and fascinating topics, which are closely related to food quality and safety, and to environment protection.

Necessity is the mother of invention. Twitter, for instance, during the Covid-19 pandemic, was very useful to disseminate education in different fields, such as horticulture (Stafne 2020) and soil science (Mills et al. 2019) and will continue to be used in the future. Innovative teaching strategies, at first a niche academic practice conducted by just a few bold educators (Galea 2006), are now commonplace (Hu and Li 2017).

The student population is now very different from that of the past, with an increasing number of students who have a limited biology background. Sometimes, we have to teach students who have different commodity interests or completely new audiences. A new generation of students needs to be trained to be adaptable to future changes, capable of critical thinking, flexible, and to be able to communicate and work in team. And, finally, we should put into teaching the same passion and enthusiasm that we put into research. Such behaviour should be accompanied by better policies, capable to put incentives into teaching. At present, indeed, the career progression system in Italian Universities, as well as in many other countries, mostly based on research products, does not provide researchers any incentive to invest in skills to improve their teaching attitude.

Acknowledgements This manuscript reflects the experience of the author at the University of Turin and contains personal opinions deriving from such experience. It originates from an invited lecture given at the International Congress of Plant Pathology (ICPP 2023, Lyon, August 20–25, 2023). I wish to thank the administration offices of the University of Turin for providing the data on student enrolment, Marguerite Jones for language revision and the thousands of students that have made my life so interesting.

Funding This manuscript has received funding from the European Union's Horizon 2020 Research and Innovation Program under grant agreement no. 817946 (EXCALIBUR) and from Fondazione Compagnia di San Paolo, call "Simbiosi - Insieme alla natura per il futuro del Pianeta", project "Biodiversità e salute delle piante - BIOSAL".
Open access funding provided by Università degli Studi di Torino within the CRUI-CARE Agreement.

Data availability All data generated or analysed during this study are included in this article.

Declarations

Ethical approval The author confirm that there are no ethical issues in publication of the article.

Competing interests The author has no competing interests to declare that are relevant to the content of this article.

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