Honoris Causa

Universitat de Lleida

Frank Forcella

Honoris Causa

Investidura com a doctor *Honoris Causa* del senyor

Frank Forcella

Universitat de Lleida

Recull de les intervencions i lliçons pronunciades en l'acte d'investidura com a doctor *Honoris Causa* de la Universitat de Lleida del doctor Frank Forcella, que es va fer al Saló Víctor Siurana del Rectorat, el dia 17 de març de 2022.

Disseny i maquetació: Edicions i Publicacions de la UdL

Fotografia de portada: Audiovisuals de la UdL

Per a més informació, visiteu la web de la Universitat de Lleida

Índex

Salutació

Mgfc. Sr. Jaume Puy Llorens

Bona tarda,

Good afternoon,

Secretaria General de la Universitat de Lleida, director de l'Escola Tècnica Superior d'Enginyeria Agrària de la Universitat de Lleida, president del Consell Social de la Universitat de Lleida, rector Joan Viñas, vicerector de Recerca de la Universitat de Barcelona, digníssimes autoritats acadèmiques i civils, membres de la comunitat universitària, senyores i senyors,

Benvinguts i benvingudes a l'acte d'investidura del senyor Frank Forcella com a doctor *honoris causa* per la Universitat de Lleida.

La importància i el valor que la universitat atorga a aquest nomenament, que és el més alt honor que aquesta institució concedeix, es posa de manifest en la solemnitat d'aquest acte, marcat per un ritual antic i d'un alt valor simbòlic..

Laudatio

Dr. Jordi Recasens Guinjuan

Magnífic rector, president del Consell Social, secretària general, director de l'ETSEA, autoritats acadèmiques i civils, membres de la comunitat universitària, doctor Frank Forcella, senyores i senyors.

Voldria iniciar aquesta *laudatio* agraint al Consell de Govern de la Universitat de Lleida i al rector Jaume Puy que hagin acceptat la proposta del Departament d'Hortofructicultura, Botànica i Jardineria de nomenar doctor *honoris causa* el doctor Frank Forcella, així com el suport rebut per part de l'ETSEA. També vull fer un reconeixement especial als meus companys i companyes del Grup de Recerca de Malherbologia i Ecologia Vegetal per estar amatents, malgrat les adversitats causades per la pandèmia, a portar a terme aquest nomenament després de més de dos anys d'espera des de la seva aprovació.

Vull fer esment també de l'acompanyament avui aquí per part de membres i socis de la junta directiva de la Societat Espanyola de Malherbologia, entre ells l'expresident i investigador del CSIC de Madrid, el Dr. César Fernández Quintanilla, i del professor de la Universitat de Sevilla Dr. José M. Urbano. I vull excusar l'absència de l'actual presidenta de l'esmentada societat, la Dra. M.D. Osuna, del centre CITYTEX d'Extremadura, que m'ha manifest el seu desig de poder-hi ser present en aquest acte, però que obligacions imminents li han impedit desplaçar-s'hi. No obstant això, em consta que segueix l'acte per videoconferència i des d'aquí el meu reconeixement i salutació.

Dr Forcella, allow me to use the Catalan language to introduce you and your scientific and academic career to the members of my university. Later, in English, I will refer to the relevance of weed science as a scientific discipline and its agronomic importance, with special emphasis on the contributions you have made in this field.

El Dr. Frank Forcella és considerat un dels millors experts en estudis sobre biologia i ecologia de males herbes d'arreu del món. Ha fet diversos treballs en l'àmbit de l'agronomia, l'ecologia vegetal i, especialment, de la malherbologia, disciplina científica que ha ajudat a consolidar i a projectar.

El Dr. Frank Forcella va obtenir l'any 1972 la titulació de llicenciat (B.S.) en Biologia per la Northeastern University de Boston; el 1977 va llegir la tesi de mestria (M.S.) en Botànica a la Montana State University i l'any 1979 va obtenir el doctorat (Ph.D.) en Botànica per la Universitat d'Oklahoma.

Un cop obtingut el doctorat, ocupa diferents càrrecs en diferents universitats i centres de recerca: entre 1979-1980, com a *assistant professor* a la Yarmouk University, a Irbid, Jordània; entre 1981-84 com a *research scientist & senior research scientist*, al CSIRO, Canberra, Austràlia; a partir del 1985 s'incorpora com a *research agronomist* al Servei d'Investigació Agrària de l'USDA. El curs 1988-89 fa un parèntesi en aquest càrrec i s'incorpora a la Universitat de Califòrnia, al campus de Davis, per portar a terme tasques de docència i recerca en Agronomia. L'any 2001 assoleix la direcció del *National Program for Weed Science*, de l'USDA-ARS, a Beltsville, Maryland, i a partir del 2001 es trasllada a Morris, Minnesota, com a *research agronomist* al North Central Soil Conservation Research Laboratory del USDA, on va assolir la direcció de recerca d'aquell centre. Els darrers anys, compagina aquesta tasca amb la d'*adjunct professor* a l'Agronomy and Plant Genetic Department de la Universitat de Minnesota. Es jubila l'any 2020.

Arran de la seva experiència investigadora, el Dr. Forcella esdevé reconegut arreu del món com un destacat líder en investigació en la biologia i en sistemes de gestió de males herbes. Uns exponents evidents d'aquest reconeixement són els premis atorgats per part de societats científiques, com l'American Society of Agronomy (ASA) l'any 2001, la North Central Weed Science Society (NCWSS) el 2008 i la Weed Science Society of America (WSSA) l'any 2000, així com els nomenaments com a *full professor* a la Universitat de Minnesota (UMN) i a la South Dakota State University (SDSU), les més de 100 ponències convidades a congressos i simposis o convidat com a membre de diversos comitès científics internacionals. Ha publicat 225 articles en revistes científiques indexades en el camp de l'agronomia, i en concret de la malherbologia. Ha estat membre del consell editor de les revistes *Weed Science* i *Weed Research*, "outstanding reviewer" de la *Canadian Journal of Plant Sciences* i analista de temes principals (*main* *topics*) de la International Weed Science Society. Ha estat nomenat expert consultor en temes agronòmics en consultories realitzades per les Nacions Unides, FAO, USDA i diferents universitats. Ha acollit i format desenes d'investigadors d'arreu del món que han fet estades al seu laboratori, i ha dirigit 14 tesis doctorals. La pràctica totalitat dels llibres publicats en llengua anglesa sobre malherbologia des de l'any 1990 citen treballs del Dr. Forcella.

I com ha ressaltat el director de l'ETSEA, cal també posar de manifest la relació que el Dr. Forcella ha tingut amb la Universitat de Lleida, i en concret amb el grup de Malherbologia i Ecologia Vegetal:

a. Ha donat suport per establir i consolidar una línia de recerca sobre modelització en l'emergència de males herbes.

b. Ha col·laborat en la difusió de resultats de recerca en revistes internacionals prestigioses en el camp de la malherbologia.

c. Ha acollit i format investigadors de la UdL al centre de USDA, a Morris (Minnesota).

d. Ha impartit diversos seminaris al Màster de Protecció Integrada de Cultius els anys 2012, 2014 i 2017.

I de manera especial, cal destacar la col·laboració establerta amb tots els membres del grup d'una manera molt pròxima i afectiva.

Però, què és la malherbologia?

But, what is weed science?

This question is still very common, not only in society in general but also within the academic world. Weed science is the scientific discipline that studies the biology and ecology of weeds, searching for the best methods of weed management in our crop fields. Along with applied entomology and plant pathology, it represents one of the three pillars of what is called plant health or crop protection. However, while the other two specialties have had more history and have been more present in agronomy studies, weed science is at a disadvantage and has profound shortcomings. It is worth mentioning, as an example, that the word "malherbología" was accepted by the Real Academia de la Lengua Española just two months ago.

Weed science took its first steps in Spain in 1989 with the creation of the Sociedad Española de Malherbología (SEMh), a society that today integrates few more than 200 members, including just over 70 researchers from public entities. In addition, and unlike plant pathology or entomology, weed science is not yet taught in many schools or faculties of agronomy in our country and until a few years ago, there were no weed science departments or chairs in Spain. This has resulted in there being a limited number of specialists, fewer research groups, fewer funded projects and fewer doctoral theses than in other plant health disciplines. This fact is extremely worrying in Catalonia, the only autonomous community in the state without a weed research group in the official agricultural research centers.

However, weeds are the agents that cause the greatest crop yield losses. Their resilience (defined by rapid growth, high fertility, the persistence of seeds or organs of propagation in the soil and especially their adaptation to management) guarantees their presence in any type of crop. In addition, chemical control methods (herbicides) make up the largest economic volume of the total plant protection products that are usually applied in crop fields. In Spain, in 2019, 370 million euros were spent on herbicides alone.

We are therefore faced with a paradox: weeds, the plants that cause great economic losses in our crops and force producers to spend a lot of money on controlling them, are not deemed important enough to encourage their study. A clear paradox between their agronomic importance and the unequal consideration in curricula or in the prioritization of lines and research strategies.

Far from the first approaches in weed science, focused exclusively on searching for control methods, today we know that a management program cannot be designed without deep knowledge on weed biology and ecology. It is in this direction that we may identify the weed's weaknesses - its Achilles heel – and optimize its control. Control not strictly dependent on a single method, but on different tools and strategies of a cultural, mechanical and even chemical nature, defining what we call integrated weed management.

The success of an integrated weed management program will depend on the knowledge gained by the technician or advisor and how it is implemented. It will not depend on the weed.

Allow me to cite a phrase from Victor Hugo:

> Il n'y a pas de mauvaises herbes ou de mauvais hommes. Il n'y a que de mauvais cultivateurs.

It is also worth noting that despite the complexity of the study of weeds, the analysis of their behavior is fascinating and never ceases to amaze scientists. Weeds existed before the advent of agriculture. And we can ask ourselves: how have they adapted to live with crops? What makes them adapt to changes in crops? We have species adapted to all types of crops, soil management systems (tillage, direct drilling) and different control methods applied: mechanical methods, manual methods ... and some weeds have even developed mechanisms of resistance to herbicides. Currently, a huge problem.

So, in this context of complexity in the study of weeds, the work of Dr. Forcella has made important contributions. These studies can be summarized in the following six research lines:

1. Design of analytical schemes and protocols to predict the presence of invasive weeds in various regions using multivariate statistical methods (novel at the time).

2. The study of the soil and the expression of the seed bank hypothesizing that the differences in the presence of weeds between soil management systems imply a differential recruitment of seeds in the soil layers. These studies resulted in the development of the "tillage decision concept".

3. The development of weed seed dormant submodels for different US regions.

4. The evaluation and improvement of decision support systems that, based on biological data (seed production, weed-crop competition), reduce herbicide-based inputs, have a lower environmental impact and increase the farmer's profits.

5. Development of the "Weed Cast program", a decision support system created at the USDA to support consultants, technicians, and students to predict the seedling

development of annual weeds in U.S. crops. Six analogous programs were later developed for countries from South America, Africa and Europe.

6. Modeling weed emergencies (with the SMT^2 model) based on soil moisture and ambient temperature. A tool for predicting the timing of weed emergence and optimizing the timing of a control strategy.

But just over a decade ago, a completely different and novel approach emerged in weed science. After years of studying how to control weeds, the question arose as to whether weeds have any role or utility in the system. If we consider agricultural systems as ecological systems, we ask ourselves: Do weeds provide any service to the agroecosystem? And so, the view of weeds as competitive, harmful, noxious organisms is modified by a more contrasting view. Weeds may not be desired, but in certain situations they can benefit the system. They can accommodate auxiliary fauna in pest control, they can favor the presence of pollinators, they are the first step in the food chain of the system, they help prevent soil erosion and compaction, they are biodiversity indicators of an agricultural landscape, and ... they can even become new crops!

Thus, this new approach in weed science has generated, in the last few years, a scientific trend aimed at finding the benefits that weeds bring to the system. In other words, to identify and use their ecosystem services.

And precisely within this new approach, the contributions of Dr. Forcella stand out especially in the establishment of new oil seed crops that are alternative to traditional crops and encourage the presence of pollinating insects. We can highlight the work carried out with the species *Camelina sativa* and *Thlaspi arvense*, species known as weeds in cereal fields that have become oil seed crops with great potential for agronomy, industry and animal feed.

The scientific specialization of Dr. Forcella in weed science has been diverse, but biology and ecology have always been the common denominator. Two tools that make it possible to understand the complexity of how organisms and systems work, whether these organisms are weeds or these systems are crop fields.

Per acabar, vull recordar de nou l'estreta relació que el Dr. Forcella ha mantingut amb la UdL, però per sobre del suport científic i acadèmic ofert sobresurt la seva generositat i bonhomia. El seu mestratge ha deixat una clara empremta en els seus deixebles i en les persones amb qui ha col·laborat. Un model de gran investigador on el coneixement científic va acompanyat d'humilitat i d'una enorme humanitat.

Membres de la comunitat universitària, us presento aquí el Dr. Forcella, aureolat amb la toga immaterial de la ciència, amb la capa d'amor als seus estudiants amb els distintius de la senzillesa i amb el birret de l'honestedat.

Moltes gràcies.

Laudatio

Sr. Jordi Graell Sarlé

Rector Magnífic de la Universitat de Lleida

Digníssimes autoritats acadèmiques i claustrals

Com a director de l'ETSEA, vull donar les gràcies al professor Jordi Recasens Guinjuan i als membres del Grup de Malherbologia i Ecologia Vegetal, del Departament d'Hortofructicultura, Botànica i Jardineria, dels qui va partir la idea de proposar al professor Frank Forcella com a doctor honoris causa de la UdL.

A més dels abundants mèrits acadèmics i científics que han estat lloats del professor Forcella, vull ressaltar breument aquells que han suposat més benefici per a la comunitat acadèmica, el professorat i l'estudiantat del nostre centre, en particular, i per a la UdL, en general, a saber:

a. El suport que ha donat al llarg del temps al Grup de Recerca en Malherbologia i Ecologia Vegetal per establir i consolidar una línia de recerca en modelització en l'emergència de malesherbes.

b. La col·laboració amb el grup en la difusió de resultats de recerca en revistes internacionals prestigioses en el camp de la malherbologia.

c. L'acolliment d'investigadors del grup de recerca de la UdL al centre de USDA, a Morris (Minnesota).

d. La impartició de diversos seminaris i conferències en el Màster de Protecció Integrada de Cultius de la UdL al llarg dels anys.

Considerats tots els arguments i exposats tots els fets, sol·licito amb tota consideració i prego s'atorgui al senyor Frank Forcella el grau de doctor honoris causa per la Universitat de Lleida.

Acte de doctorat *Honoris Causa*

Dr. Frank Forcella

Índex

Weeds: A Love / Hate Relationship

Frank Forcella, USDA-ARS Research Agronomist & University of Minnesota Adjunct Professor of Agronomy (Retired)

Love and hate? Let me explain with humor. Imagine a comic in a newspaper (*comic de periodico*), then imagine four flowers in that comic. *La primera flor es mama, la segunda flor es papa, la tercera flor es su hija adolescente, y la cuarta flor es avena loca*. The young girl says, "*Mama, Papa, este es mi nuevo novio*." And the parents respond, "*¡Caramba, él es una mala hierba.*"

Weeds are the bad boys of the plant world. Farmers are similar to Mama and Papa: Weeds are not good. Weeds are bad. Farmers do not want their crops to be close friends with weeds. But at least some weed scientists are similar to teenage girls. To a weed scientist, weeds are fascinating.

Yes, weed scientists try to discover methods to control weeds, but weed scientists also are amazed at the abilities of weeds to survive, to reproduce new plants, to evolve genetically, and to return next year to annoy us yet again – despite everything that is done to kill them. Any plant, any organism, that can resist this onslaught of destruction deserves our admiration, our respect – even if we hate them sometimes.

Consider how much money we spend to control weeds. Just for herbicides in the USA, we spend approximately €3 billion every year. That is a lot of money.

Even with such use of herbicides, weeds still reduce crop yields by 12%, on average, which is valued at about €20 billion of yield losses in the USA. (I shall discuss Spain below.)

There are 5000 weed species in the USA, with 73% introduced from other continents, many from the Mediterranean Basin. Thus, there are plenty of species to cause problems in a wide diversity of environments.

The History of Weeds and Weed Control

Weeds have existed since humans first decided they did not like certain plants, and probably much earlier than the time-frame typically given as the beginning of agriculture – 12,000 years ago. At a 23,000-year old archeological site near the Sea of Galilee (Israel/Palestine), seeds and/or fruit of eight crops were found: Wheat (trigo), barley (cebada), pea (guisante), lentil lenteja), almond (almendra), fig (higo), grape (uva), and olive (aceituna). What else did the archeologists find? Did they find any weeds? Yes, 13 species of weeds were found. The three most common species were: galio de tres flores (***Galium tricornutum***), malva menor (***Malva parviflora*****),** **and** cenizo blanco (***Chenopodium album***). Most modern farmers in Spain would recognize each of these species.

How did our ancient relatives control these weeds? Hand pulling of weeds has occurred since that time. Did they use any tools? Hoes (*azadas de cultivos*) may have been the first tools used for weed control. Wood from trees and bones of animals were used as hoes in ancient Egypt – 4000 years ago.

Since Egyptian times until about 1700, not much progress was made. Yes, farmers used some farm animals (*burros y bueyes*) to pull ancient tools to control weeds, but these tools still were clumsy and inefficient. Some people think that Jethro Tull, in Britain, was the first to develop hoes made of steel *(azadas de acero*) in about 1700. But, apparently, he used these tools mostly for crushing clods of soil to prepare seedbeds rather than for weed control. For Senor Tull, weed control was secondary. Whatever the case, hand hoes made of steel, or steel hoes pulled by farm animals and later by tractors, have been used for weed control since that time.

Emergence of Weed Science as a Scientific Discipline

Despite the invention of steel tools for controlling weeds, during the next 200 to 250 years there was no formal scientific discipline or category within agriculture devoted to weeds. There was no "Weed Science."

Not until the year 1911 was the first university course on weed control taught, in this case at Oregon State University. Information about weeds may have been taught to students before this, but only as part of more general courses on crops. Even 30 years later, few universities taught courses in weed science.

The first book on weed control (*Weeds of Farm Land*) was published in Britain in 1920. The book was written by Winifred Brenchley. (*Winifred? En inglés el nombre "Winifred" es femenino.*) Yes, Dr Brenchley was the first person to write an entire book on weeds. She helped to create Weed Science. (Remember the aforementioned comic about teenage girls and weeds? Older women may not love weeds but, apparently, they learn how to control weeds.) Despite the university courses and the book by Dr Brenchley, there still was no discipline of weed science in Britain, or anywhere else in the world.

Weed Science became a recognized scientific discipline as a product of war, World War II specifically. Indeed, Weed Science could be considered a "war baby." The Allied Forces (Britain & the USA) developed 2,4-D in about 1941. Why? To control weeds? No. They wanted to kill potatoes and rice. (*Quien come muchas papas? Quien come mucho arroz*?) The Allies wanted to starve the Germans and Japanese into submission by stopping the production of potatoes and rice.

Are potatoes and rice weeds? Well, yes and no. If they grow where someone does not want them to grow, then they are weeds. In this case, potatoes and rice were growing in the fields of "enemies." As it happens, however, 2,4-D did not kill either of those two crops. Today, in fact, 2,4-D is labeled for use in potato and rice crops to control "real" weeds! Thus, ironically, Weed Science started as a failed experiment!

However, even though 2,4-D did not control potatoes and rice, the scientists working on 2,4-D during World War II immediately discovered that 2,4-D did control many other plants. And soon after the war ended, 2,4-D and other related herbicides (e.g., 2,4,5-T) were made and sold by companies to farmers and others (e.g., golf course managers). "Weedone" was the trade name for 2,4-D. By the 1950s there were hundreds of other herbicides.

The journal *Weeds* (now *Weed Science*) began in 1951. The Weed Science Society of America was created in 1956. In Europe, the European Weed Research Council started in 1958 and changed to the EWRS in 1975. The journal *Weed Research* was launched in 1960. So, within 15 years of the discovery of 2,4-D, agricultural researchers and teachers had journals and scientific societies devoted to weed science.

The Importance of Weed Science to Spain

According to a European Commission Report published in 2021, agricultural imports to Spain in 2020 were valued at €31 billion (*31 mil millones* €), whereas agricultural exports from Spain in 2020 were valued at €51 billion. Thus, Spanish agriculture had a net positive balance in 2020 of €20 billion. That is good.

What products account for Spain's agricultural production?

Animal production (especially pigs) accounted for 40% of Spain's agricultural economy, and crop production accounted for 60%. The major money-making crops were vegetables (20% of agricultural economy), fruits (20%), cereals (9%), olives (<3%), and all other crop categories represented < 1 or 2% of financial agricultural market. Do the extremely high market shares of vegetables and fruits provide rationales to weed scientists in Spain for how to divide their time and efforts in terms of research priorities?

European Parliamentary Research Service

Two related publications were released recently by the European Parliament. These were *The Future of Crop Protection in Europe* (2020) and *Cost of Crop Protection Measures* (2021). These publications are about "plant protection" generally (that is, insects, diseases, and weeds). I shall try to summarize as best I can the portions of the documents applicable to weeds and to emphasize information relevant to Spain.

First, I should add that I perceived a bias in the documents regarding chemical control generally, and herbicides specifically. The authors emphasized non-chemical alternatives for managing weeds, but simultaneously they recognized that herbicides remain the technique of choice for most farmers. Fifty years ago when I was a young scientist and trying to read widely about scientific studies of weeds from around the world, I devised an adage:

> If you want to know how a weed grows, ask a weed scientist from Europe.
>
> If you want to know how to kill a weed, ask a weed scientist from America.

Although weed scientists from both continents show wide variability in their philosophies about weed management, my world view from 50 years ago has not changed very much. And that world view is confirmed by the authors of two European Parliamentary reports. The reports stress seven broad categories of crop protection practices in Europe: mechanical techniques, precision agriculture, plant breeding, biocontrol, induced resistance, application of ecological principles, and lant protection products (PPP).

Tellingly, PPP was listed last. Does that say something about the philosophies of the authors? In the sections below, I shall provide my thoughts on each of these categories starting with PPP (partly out of mischief, but primarily because it remains the most commonly used method to control weeds).

Plant Protection Products

I shall try to emphasize herbicides, but in some cases I have to include insecticides and fungicides. How much herbicide is applied in Spain specifically and Europe generally? In the European Union, 130 million kg of herbicide active ingredient was applied in 2018. (The active ingredient [ai] usually is about ¼ to ½ of the product that famers apply.) In Spain, 17 million kg ai was applied that same year. These rates of application have remained stable for the past 10 years. France uses the most herbicide: 34 million kg ai. It is #1 in Europe in terms of herbicide use. Spain and Germany share the #2 rank in Europe.

How much herbicide is applied per hectare? Spain has 14 million ha of crops of all types. (Spain is #1 in Europe.) France is #2 with 12 million ha. Thus, the average herbicide application rate in Spain is about 1.2 kg ai/ha. If that seems like a lot of herbicide, then compare it to your northern neighbor. In France the application rate is 2.8 kg ai/ha.

What is the cost of PPP? For all of Europe, the cost of applying PPP is €128/ha. In Spain, the average cost of using PPP is €103/ha. Keep in mind, however, that enormous variation exists across crops in Spain: €1164/ha for horticultural crops (e.g., vegetables) and only €37/ha for arable crops (e.g., wheat). Spain has 14 million ha of crops of all types.

Thus, Spain spends about €1.5 billion (1.5 mil millones €) for crop protection. France, with 12 million ha, spends 2.4 billion for crop protection, which is more than any other European country.

What is the cost of plant protection chemicals compared to income from crops? The average value of Spanish crops is €1477/ha. Thus the use of plant protection products represents, on average, about 7% of a farm's income. (*Muy barato. No mucho dinero.*)

So, that is a summary of the use and costs of chemicals in Spain. Now let's think about alternatives.

Mechanical Weed Control

Mechanical techniques are the primary forms of weed control in organic crops (i.e., eco-farming). In organic crops, weeds typically are controlled with simple mechanical tools used by farm laborers. According to a recent report in "Business Insider España," labor in Spain costs employers about €23/hour. In the organic arable farming sector, hand weeding takes between 10 hours/ha in crops like cereals, and up to 200 hours/ha in high-value crops like onion.

Calculate the costs for weed control: €230/ha in cereals and up to €4600/ha in onion. Remember, the average value of Spanish crops is €1477/ha. Thus, labor costs might range from 16% to 311% of the value of the average crop. (*Muy caro. Mucho dinero.*) Of course, the use of average crop values and ranges of weed control costs greatly distort reality, but the basic message remains intact. That is, the costs of manual labor for weed control in organic crops is much higher than that for herbicides. Thankfully, many new tools and new systems for using those tools (as well as new systems for using older tools) are being developed, and this may lower the cost of weed control dramatically. Categories of these new tools are described briefly below.

Other mechanical techniques besides hand-hoeing include

(1) Mechanized weeders, such as plows, chisels, harrows, cultivators, rotary hoes, mowers, pullers, etc.. These are the mainstays of mechanical weed control, and when coupled with crop sensors, weed maps, and other new technologies, they likely will be used for many

years into the future. One example are the new "intra-row" cultivators, which disturb soil and kill weeds between individual crop plants *within* a crop row. Crop sensors are intimate accessories for intra-row cultivators.

(2) Electric weeders ("weed zappers") were conceived to electrocute weeds. The concept seemed to arise in the 1970s and 1980s, then stalled, but has had renewed interest in the last 10 years. Little information is available on this concept.

(3) Thermal weeders include flame weeders, steam weeders, and most recently, laser weeders. These concepts have taken hold, especially in northern Europe and California. Flame weeding, in particular, seems well-suited to widely spaced vegetable crops when coupled with crop sensors. Steam weeding can be used to cripple emerged plants, and the concept also has been used to kill buried seeds. Laser weeding looks fascinating, but the technique is still too young to assess with confidence. Economics plays a large role in the feasibility of thermal weeding being used on a large scale.

(4) Abrasive weeders use high velocity gritty materials to shred emerged weeds. Grit materials can range from sand from local field soils to various agricultural residues, such as bone meal (from abattoirs), shells of walnuts (*nuez*), grape pomace, pits of olive fruits, etc. Organic fruit farmers in California are using the technique, but it is otherwise too early to know if it is practical.

(5) Weed seed harvesters can be used at the time of crop seed harvest. This technique was conceived in Australia and has been tested and adopted in several countries. Its focus is on the "future control of weeds." It does not alleviate crop-weed competition in the current year. Analogous devices are known as "weed pullers," which uproot mature, seed-bearing weeds that are taller than the crop just prior to crop harvest. The uprooted plants are placed in carts for later disposal. These techniques work well for weeds that retain their seeds until crop harvest. Not surprisingly, recent research shows ecological replacement of seed-retaining weeds with weeds that shed their seeds early.

(6) RTK-GPS (Real Time Kinematic [=motion] – Geographic Positioning System) guidance can be used in connection with many of the mechanical techniques mentioned above. The popularity of guidance systems is increasing quickly. Most new tractors have them,

but they are not yet used for weed control by many farmers. This almost certainly will change in the near future.

Many of the tools mentioned above are the primary tools for controlling weeds in organic (ecological) agriculture. Ironically, any mechanical technique that kills weeds (or weed seeds) probably also kills other organisms in the soil or on the soil surface. For instance, imagine the effects of any of these tools on ants, earthworms, or predatory beetles. Imagine the effects on soil microbes and the evolution of CO_2 from oxidation of soil organic matter. Consider the effects on soil aggregate stability, water infiltration, and soil erosion. All of these techniques have unintended consequences for agroecosystem integrity, stability and biodiversity.

Precision Agriculture

Precision agriculture normally is thought to emphasize location or site specificity. That is, where are the weeds located in the field and relative to the crop? The tools used to control weeds in precision agriculture can be chemical, mechanical, electrical, or thermal. Most of these tools depend on the spatial separation of the weed and the crop.

Precision weed control using non-chemical methods is advancing relatively rapidly, especially in high-value horticultural crops. Precision herbicide applications also are occurring, but the use of this technology is not progressing as quickly as was first imagined by weed scientists and engineers for large-scale cropping of wheat, maize, soya, rice, etc.

This lack of adoption may be due, in part, to a "missing link" in precision weed control. That missing link is *precision timing* tied to *spatial variability*. In the same way that variability occurs within the spatial extent of a weed population, so too does variability occur in the timing of emergence, growth, and development within a population of weeds (one species), as well as across populations of weeds (many species). Precision timing of weed control is essential for widespread adoption of precision weed management in large-scale agriculture. Spain is fortunate in that the weed scientists at the University of Lleida are some of the world's experts in this area of weed behavior.

Related to spatial variability and precise timing in precision agriculture is the idea of *decision support systems*. Few humans have the ability to integrate in real time information involving crop and weed behavior, weather, soil conditions, and efficacies of a multitude of control options. Hence the value of DSSs. However, to date, DSSs have NOT been adopted extensively by farmers.

RTK-GPS units cost roughly €15,000 each, whereas standard GPS equipment is about €4000, but this standard GPS will be less accurate. Some precise applications even require GPS equipment on both the tractor and the weeding device that follows the tractor. Such an investment provides 2-cm accuracies and allows the tractor to be driven at higher speeds, which increases the rate of weeding (ha/hour) and thereby decreases labor costs.

Sensor-based methods for weed detection, identification and quantification plus high-resolution spraying (with an exact dosage for each nozzle on the spraying boom) currently cost roughly €100,000. An investment such as this likely will occur only on a large and profitable farm. Apparently, robotic applicators are already being offered by contract applicator companies as a service (e.g., weed control for €200/ha). However, this technique is not yet widespread in practice. Again, the cost is sufficiently high that only very profitable farms are likely to use this service. On the optimistic side, several robotic machines with precision spraying are in development. The costs of these systems are uncertain but will probably decrease as they become more common.

New Breeding Techniques

Many European countries have resisted GMO technology, which hampers the development of new crop genotypes. A clever adage in response to this resistance is: "Regulate the product, NOT the process." In other words, whether GMO technology was used to make a new crop is not important. The value and safety of the new crop is what matters. Is this true? I do not know, but my instinct tells me it is.

What is true for certain is that molecular biology has had a major impact on plant breeding. Twenty years is no longer required to advance a new crop variety to the marketplace. The term "speed breeding" captures precisely what is occurring in the plant breeding world.

For weed suppression, what traits are important for new crops? The most critically important traits are rapid germination, emergence, and leaf area expansion. Other traits are bound to be useful as well, but the rate at which leaves of a crop expand and cover the surface of the soil is most critical. This conclusion has been reached for both grain and forage crops but, to date, very little effort has been expended by plant breeders to develop weed-suppressive or weed-tolerant plants. Genes encoding leaf area expansion have been identified in Arabidopsis (*BrANT-1, ARGOS, pPLA, CDAG1*, etc.) and can be transferred to other species (e.g., *colza, rapa*, etc.) via new biotechnological procedures with relative ease. Cultivars with weed suppressive abilities via rapid rates of leaf area expansion should be high on the "to do" list of modern plant breeders who worry about agricultural sustainability.

Biological Control

Biological control agents have a long history of success for reducing the impacts of several very important species of weeds. However, those weed species were often most serious in aquatic environments, grazing lands, and natural environments. Biocontrol has not been widely effective for weed management in crops.

When biocontrol has been successful, it targeted specific weeds – that is, one species of weed for each biocontrol agent. Biocontrol is not effective on weeds generally and, therefore, biological control remains a small (but important) form of weed management for select weed species.

Crop-Induced Resistance

Weeds induce changes in a crop's transcriptome. (A transcriptome is the sum total of all the messenger RNA molecules expressed from the genes of a plant.) This phenomenon was first identified in maize. Maize genes that are consistently up-regulated by the presence of weeds include *PMT5*, which encodes a sugar transporter in leaf tissue, and *NUCLEOREDOXIN 1*, which produces enzymes involved with oxidation-reduction processes.

Can these genes (or other, as yet unknown genes) be altered to allow maize to either (a) compete better with weeds or (b) tolerate the presence of weeds? The answers are not yet known, but crop-induced resistance to weeds is not fantasy. There is cause for excitement in this new development in weed science.

Genetically Diversified Cropping Systems

Diversity in cropping systems means using crops with contrasting dates of planting, harvesting, and fertilizer applications (and amounts), as well as differing dates (and types) of mechanical and chemical control. Contrasting dates of crop management and types of crop management means continual and seemingly random disruptions of the life cycles of weeds associated with those crops. These disruptions affect all types of weeds, including winter annuals, summer annuals, biennials, and perennial species.

In the Corn Belt of the USA, where I live, maize and soya are basically the only crops. Why? Because they make the most money for farmers. Thus, the difficulty in diversifying a cropping system is finding a suite of diverse crops that generate economically viable profits for farmers. Recently, we have been trying to include winter annual crops in rotation with summer crops (maize and soya) in a "relay" system. That is, we want a "relay team of crops." (More about relay crops, below.)

Ecological Principles

The concepts of crop diversity and other ecological principles listed above cover most of the ideas concerning Ecological Principles expressed by the two European Parliament reports.

Weeds as Good Boys, not Bad Boys

Another definition of a weed is a plant whose value has not yet been discovered. A weed's value may not always be obvious. Some weeds serve as critical components in the functioning of agroecosystems. Consider the following possible roles of weeds: (1) suppression of soil erosion, (2) improvement in soil structure, (3) facilitation of infiltration and percolation of rain water and snow melt, (4) carbon sequestration, (5) nesting habitat for various animals, (6) forage for herbivores, and the related role of (7) nectar and pollen resources for pollinators.

I shall not discuss all of these roles, just the last role, which is my favorite. Some weeds have showy flowers. If these weeds grow in field margins and attract differing groups of pollinators, they often improve seed yields of adjacent crops such as canola (*rapa*), dry bean (*frijoles*), soybean (*soya*), sunflower (*girasol*), etc. Clearly, increased crop seed production is a positive contribution of these weeds to agriculture.

Those same weeds also provide food for pollinating insects. Those insects will not only pollinate additional plants (both crops and weeds) but also serve as prey for insectivores – predators – within the ecosystem. Ecosystem complexity and health can increase because of weeds.

I mentioned earlier the idea of "relay teams of crops" (*equipo de relevos de cultivos*). One of these crops is a new crop and a former weed. Its historical name in English is field pennycress (*Thlaspi arvense*), but it now has a new name as a crop: CoverCress. The same species has six common names in Spanish. You may know it as *telaspios*. (The name in Catalan is *traspic de camp*.)

We sow CoverCress in autumn after we harvest wheat or silage maize. It germinates quickly and forms small plants called rosettes. The rosettes sequester most of the available nitrate and phosphate in the soil that remain from the previous wheat or maize crops. The rosettes are dormant during winter, but they still protect the soil from erosion caused by wind, rain, and melting snow. As the rosettes resume growth in spring, soya or sunflower seeds are planted in the growing CoverCress. As the soya or sunflower emerge, the CoverCress begins to flower. There are no other flowers of any other plants at this time, except perhaps for dandelion (*diente de lion*; *Taraxicum officinale*).

The flowers of CoverCress attract many early-emerging pollinators that seek its nectar and pollen, including 28 species of bees (Hymenoptera), as well as many valuable species of flies (Diptera) in the family Syrphidae. The larvae of Syrphid flies are predatory and eat aphids that attack the soya plants emerging under the CoverCress canopy. Thus, a weed, pennycress, is now an oilseed crop, CoverCress, that produces economically valuable industrial oils, sequesters atmospheric carbon, enhances water quality, protects soil, feeds important pollinators, and hosts biocontrol agents that guard other crop plants.

What is not to love about a weed with those qualities?

Discurs de cloenda

Mgfc. Sr. Jaume Puy Llorens

Em plau adreçar a tots els assistents unes paraules.

La Catalunya interior viu de l'agricultura i la ramaderia. El 16% del PIB català prové del sector agroalimentari, que mou 38.000 milions d'euros i dona feina a 164.000 treballadors, segons dades del 2018.

És el primer sector econòmic del país i l'àmbit més dinàmic de l'economia catalana amb capacitat d'exportar (actualment, el mercat internacional suposa ja un 60% de les vendes) i d'atreure importants inversions estrangeres. Però la seva importància va més enllà del pes estrictament econòmic: en aquest sector, Catalunya és pionera en innovació i en tecnologia vinculada al producte i la seva transformació.

Tot i això, hi conviuen realitats molt diferents entre si, tant en nombre de treballadors com en ventall de salaris i processos productius, aplicacions tecnològiques o internacionalització d'empreses.

El subsector primari és l'origen de tot. Engloba el 34% dels treballadors, però només produeix el 12% dels ingressos totals. El darrer segle ha sofert una gran transformació.

A escala mundial, des de l'inici del segle XIX, la població mundial ha passat de 1.000 milions a 7.500, i l'agricultura ha estat capaç d'incrementar la seva producció a un ritme semblant al de l'increment de la població.

Entre els factors que ho han fet possible, cal esmentar la fertilització aprofitant la producció de fertilitzants nitrogenats a partir de nitrogen atmosfèric (100 milions de tones de fertilitzants per any amb el procés Haber-Bosch), la millora vegetal que ha produït noves varietats de llavor i llavors híbrides molt més productives que les tradicionals, i la tecnificació i la mecanització de les tasques agrícoles.

Aquest gran èxit té també les seves ombres. La mecanització i l'increment de la producció han anat lligades a la pèrdua de llocs de treball i pèrdua d'ingressos per al sector en relació amb altres activitats, és a dir, hi ha hagut una caiguda de la rendibilitat de l'activitat agrària i molts petits productors han hagut d'abandonar o s'han transformat en productors a temps parcial.

En l'àmbit de l'Estat, segons dades del Ministeri d'Agricultura i Pesca, els darrers 40 anys la població que viu en municipis de menys de 10.000 habitants han passat del 57% al 23%.

En el nostre entorn, un estudi recent de la UdL indica que 93 dels 231 municipis de Lleida estan en risc de despoblament.

Els efectes d'aquest despoblament han estat malèvols, tal com retrata la directora de cinema Carla Simón, guardonada a Berlín, que "no s'explica el que està passant, si de cas, es busca un punt de vista poètic, ningú mostra com és de dur. Veig els meus oncles en aquesta feina brutal i soc testimoni de com volen que els meus cosins es dediquin a una altra cosa".

Segons criteris economicistes, i no per la racionalitat agronòmica, ha progressat el monocultiu. La conseqüent reducció de la biodiversitat ha encoratjat l'aparició de plagues i malalties de les plantes i ha fet créixer l'ús de productes fitosanitaris. L'aplicació poc racional d'aquests productes ha trencat la cadena tròfica i ha forçat més intensificació encara de l'ús de fitosanitaris.

Aquesta descripció podria portar a una imatge simplista i negativa de l'agricultura, però això no se sosté amb la realitat actual. Aquests problemes s'han reconegut i s'han anat ressituant amb avenços tècnics i un nou concepte d'agricultura més lligat al de sistema ecològic i de sostenibilitat ambiental. La producció agrícola s'està enfocant avui des d'un punt de vista integral de sistema: sòl, fertilització, reg, maneig, conreus i material vegetal formen un tot i s'organitzen per posar un ull en la producció i l'altre en la sostenibilitat entesa com la conservació dels sòls, en l'economia circular amb la reutilització de subproductes o en la lluita contra l'increment de temperatura i el canvi climàtic transformant els sòls en embornals de C, i minimitzant l'ús d'aigua i la contaminació dels aqüífers per nutrients, fitosanitaris o antibiòtics. L'harmonia entre la producció agrària i l'entorn és fonamental, motiu pel qual la preservació de l'entorn és cada vegada més important a les polítiques agràries. L'agricultura és actualment una activitat molt tecnificada on conflueixen moltes àrees científiques. Avui, l'agricultura de ponent aplica tècniques poc invasives, de mínim maneig o de sembra directa, que permeten augmentar la quantitat de matèria orgànica en el sòl i minimitzar l'erosió i la degradació dels sòls, amb una mínima alteració en la composició, estructura i biodiversitat del sòl, respectuosa en la seva conservació, amb reg controlat, diversificant els cultius, emprant materials millorats que s'adaptin a les condicions del medi, protegint-los de forma integrada i buscant sistemes de producció més neutres respecte al canvi climàtic. I tot això es combina per aprofitar cíclicament els subproductes, amb la producció primària ramadera i explotacions cada cop més modernes, tecnificades i competitives. Només cal fer una passejada per la Fira de Mollerussa d'aquest cap de setmana per comprovar-ho.

Aquest sistema actual és impensable sense una estratègia intel·ligent de control de males herbes emprant herbicides selectius o totals en combinació amb rotacions escaients de matèries actives, conreus, dates de sembra, vigor, estadi de desenvolupament de la planta, cobertes vegetals per mantenir el cultiu net i evitar l'aparició de resistències...

Today, as explained in the laudation, the University of Lleida has awarded an honorary doctorate to a researcher who has dedicated his academic career to weed control and biology, generating a series of guidelines used extensively throughout the lands of Lleida, both in the wide dryland as well as in the irrigated areas. The application of herbicides in Europe, as well as in Spain, and their effect on crop yields highlight the outstanding practical importance of Dr. Forcella's results.

His lecture has been an amusing and wonderful journey through the history of weeds and weed control that has revealed his ability to explain complex things in simple words, his quality as a teacher and his enthusiasm for science, technology and its application to the main challenges we face with strategies and tools that combine chemistry, biology, physiology, genetics, statistics and artificial intelligence.

As the career of Dr. Forcella illustrates, our mission is not limited to just the production of new knowledge, but also entails sharing this knowledge with the stakeholders so that it results in real progress.

En línia amb ell, apostem per una concepció integradora i social de la ciència, que es resumeix en el que anomenem ciència oberta, i que és molt més que publicar en accés obert, és una manera d'entendre el treball científic amb i des de la societat per participar dels seus problemes, fer noves propostes i transformar-la. Hem d'obrir la ciència perquè la societat en pugui ser impulsora, partícip, finançadora, receptora i avaluadora. Hem d'obrir la ciència perquè si no és inclusiva, perd utilitat i perilla el seu objectiu final de ser útil i rellevant, i es transforma en progrés. Hi ha una dita que aconsella: "Visita sovint els amics, si no vols que apareguin punxes i males herbes al camí." Quan ciutadania i ciència no van juntes, el buit l'aprofiten les ombres, les llegendes, els recels i la pseudociència. El rigor i la independència han de ser característiques de la universitat.

La població del mon seguirà creixent els propers anys i, per tant, també la necessitat de produir aliments. El debat sobre la possibilitat d'alimentar tothom en un futur és obert i polèmic. Atès que les àrees de producció agrícola en ús estan pràcticament al límit, si no s'amenacen més les àrees forestals, caldrà canviar la manera de fer créixer els nostres cultius, aprofitar millor els aliments que produïm (avui més d'un 35% es malmeten) i millorar-ne la distribució si el que volem és evitar una propera crisi mundial. Alhora, haurem de fer canvis importants en la nostra dieta alimentària.

Tenim eines per treballar en aquests reptes. La genètica molecular, la biotecnologia, les tecnologies de sensorització, la intel·ligència artificial, el big-data són eines que poden aportar, com hem escoltat, una important contribució per assolir aquests objectius. La recerca ens ha d'empoderar per superar aquests reptes, millorar les condicions de vida i construir una economia sostenible i integradora. Hem de prendre model de l'actitud tossudament resilient de les males herbes que sobreviuen a les condicions més adverses pel nostre afany de superar les nostres amenaces.

The future is unknown, but it will certainly require teachers like our honorary doctor, passionate about his job, observant, with integrity and resilience. It is our pleasure to welcome him to the lecturer's Senate of the University of Lleida. What makes the main difference is people, their involvement, their effort and their enthusiasm for shared projects.

Sense agricultura i ramaderia, almenys de moment, no hi ha alimentació humana.

Moltes gràcies.

Universitat de Lleida