Transformation of Plant Science in Our Time—the Contribution of Jozef S. Schell (1935–2003)

Editor's note: Plant Physiology does not ordinarily publish obituaries, but is making an exception in this issue to honor Jeff Schell for his enormous contribution to plant science.

The ability to introduce genes into plant species has revolutionized fundamental research and allowed for the fastest development of new varieties in the history of commercial agriculture, as all readers must know. This technology probably represents the most significant breakthrough in plant breeding for the 20th century. The relatively small number of pioneers of this new technology in plant science have been honored by the scientific community, governments, awarding foundations, and scientific academies. With the recent passing away of Jozef (Jeff) Schell (April 2003) , it is appropriate to recall his contribution. He played an enormous role in both the discovery underlying Agrobacterium-mediated transformation, and the vision for how this technology could and should change opportunities for humankind forever.

Why was Jeff's influence so noteworthy? There are many reasons. He was an exceptional scientist: charismatic, physically strong, visionary, adventurous, and politically astute. He was an advocate for governments and industries, and he had an immense capacity for hard work. His vision ranged from a comprehension of the intricacies of the wonderful evolutionary process of Agrobacterium T-DNA transfer, to a world where many plants used by people could and would be improved as never before. As the subject of plant genetic engineering matured, he believed, and continuously emphasized to all, that plant biotechnology was essential for our crowded world in order to give everyone a reasonable standard of living and a sustainable environment.

Many research scientists who employ Agrobacterium transformation routinely, and obviously the millions who eat transgenic food or grow transgenic cotton, do not necessarily know how the gene-transfer discoveries were originally made and harnessed. Although many reviews have been written on the subject, it is not widely appreciated that in the 1960s and 1970s Jeff Schell and his colleague Marc Van Montagu in Gent, Belgium, worked as microbiologists, as bacterial geneticists, and not as plant scientists. However, they, like a few others, became intrigued by the long-established evidence that some soil bacteria provoked formation of cancerous tissues on certain plant species. Their papers of the day focused on bacterial genetics, with the discovery, isolation, and mapping of plasmids and recognition

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of different kinds of agrobacterial plasmids. They described the production of different metabolites, notably nopaline and octapine, by the tumors, and eventually the transfer of T-DNA. Their fundamental research was driven by questions in bacterial genetics and the evolution of an extraordinary plant-microbe interaction; one in which plant cells were induced to proliferate, make, and excrete a metabolite that the particular Agrobacterial strain was exquisitely capable of using as a nitrogen and carbon source and that allowed it to compete more effectively with other microbes. Plant genetic engineering did not emerge as a topic until it was proven that bacterial T-DNA was incorporated into plant chromosomes. Even when this was proven, the job of genetically dissecting the functions of the T-DNA, learning how to isolate the Ti plasmid, learning how to clone the DNA, to create deletions, to recombine DNA into plasmids in vivo, to introduce novel genes into T-DNA on the Ti plasmid, and to shuttle DNA from *E. coli* to Agrobacterium were the stuff only bacterial geneticists could work out. Almost no plant scientist had these skills at the time. Jeff and Marc were the leaders in this new field because they had created the opportunity, were skilled in the thinking and the required techniques, and most importantly, had the foresight to know what was there to be discovered.

Jeff's first publications in the late 1950s and early 1960s were concerned with carbon metabolism in

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bacteria. These studies were followed by ones on modifications of phages and restrictions by their hosts. His first paper, coauthored with Marc Van Montagu, on Agrobacterium-related DNA was published in 1972 and focused on Agrobacterium phages. With Rob Schilperoort, he described in 1973 the detection of Agrobacterium DNA in sterile crown gall tissue cultures. In 1974, his group showed that a large plasmid of Agrobacterium was essential for crown gall induction, and this was followed by a series of papers on the plasmids. The isolation of the Ti plasmid was described in 1976, and this breakthrough opened up many new opportunities to study its DNA. By 1977, several groups including those of Schell and Van Montagu in Gent, Mary-Dell Chilton in Eugene Nester's laboratory in Seattle, and Schilperoort's lab in Leiden were actively testing the idea that the Ti plasmid of Agrobacterium might provide a means of inserting genes into plants. In 1978, Jeff and his colleagues (including Marc Van Montagu) published 18 papers covering the origins of crown gall by Ti plasmid transfer and the manipulation of the Ti plasmid by various bacterial genetic tricks, including transposon mutagenesis, cointegration, and transfections to reveal more about the plasmid, the genes it contained, and the requirements for crown gall induction. In 1980 the Gent group published 20 papers, many being symposium articles, to get the Ti–plant cell transformation message out to receptive scientists. By the time the seminal papers were published in 1983, showing the expression of novel chimeric genes introduced into plant cells using a Ti plasmid-derived vector, Jeff and his colleagues had published some 150 papers. Then followed many details of the Ti plasmid genes, their role in oncogenesis, and the behavior of these genes when transferred into plants. Some 23 papers were published in 1984 describing the development of useful vectors and the transfer of several more foreign genes into plants. During this time he also studied the Ri plasmid, the equivalent of the Ti plasmid, in *Agrobacterium rhizogenes* and its function after transfer to plants cells. Once the subject was truly well established, the concept of plant genetic engineering became a topic of worldwide debate, and the plant scientific community embraced these technologies to literally transform the whole field of plant science. During this period, Jeff and many colleagues, including students and postdocs, and collaborators in other laboratories published a large number of papers (another 449 until his death in 2003) on Ti plasmid biology, transformation vectors, plant gene discovery especially in Arabidopsis, promoter analyses, hormone biology, Rhizobium genetics, and plant genetic engineering.

The enormous number of papers that carried his name, first from Gent and then from his very large group in the Max Planck Institute for Plant Breeding, Köln, Germany, are a witness to the huge contribution he and his colleagues made to the development and propagation of plant transformation and molecular genetics. However, the expansion of a technology and its adoption into another area of science worldwide takes not only skilled experiments and provocative publications. It takes teaching of a vision to scientists, research funding agencies, industries and governments, and the training of a new generation of scientists. Jeff did all of this, unceasingly, for twenty years. He had a major impact on students, established scientists, plant breeders, industries, funding agencies, governments, as well as scientific societies and the general public. During the 1980s and 1990s, he sustained a punishing schedule of lectures around the world. In the 1980s he was sought by nearly every plant molecular biology conference, and he wanted to attend them all to learn, to teach, to inspire, and to open up the practice of plant molecular genetics.

If he gave much to plant science everywhere by his teaching, he gave much to European science by accepting in 1978 the Directorship of the Max Planck Institute for Plant Breeding Research in Köln, Germany. This appointment gave Jeff the opportunity to establish a very large team of scientists, to develop the new approaches to plant science, and to train students and postdocs. The position also gave him enhanced authority to talk to European governmental agencies and the European Union (EU). In the early years of plant genetic engineering, he also advised Monsanto, the company that was to become the foremost crop genetic engineering multinational. He also forged a long-term, mutually beneficial, relationship between the Max Planck Institute and Bayer, a company located close to the Max Planck Institute in Germany.

Jeff was a true European. The EU started to offer substantial funds for research in the 1980s, and Jeff and colleagues at the Max Planck Institute in Köln saw the value and necessity for this pan-European resource to spearhead the research that could help address the substantial agricultural, economic, and environmental problems of the future. He taught and lobbied EU scientific leaders about the new plant science. To improve the funding and management of EU plant science programs, the Max Planck Institute and the John Innes Centre (Norwich, England) –the two largest centers for plant molecular genetics in Europe –formed a legal entity under Jeff's chairmanship. Much was changed during the 1990s via this organization and Jeff's tireless and influential leadership. He saw the needs of European and global societies and was not afraid to articulate the opportunities, needs, and requirements for change to anyone.

While being a Director of a team of well over 100 scientists, an international leader, and an advocate for European science and plant molecular biology for agriculture and the environment in general, Jeff

found time to do many of the ordinary things that senior scientists do write and review grant proposals and papers and mentor students and postdocs in his laboratory. He was a senior editor of The Plant Journal from 1990 to 1998. He also held the great distinction of being the Chairman of the European Molecular Biology Organisation (EMBO) Council from 1990 to 1995. EMBO is an organization much revered in Europe and via his service to EMBO, Jeff gave much to molecular biology as a whole. Of course, he sat on many boards and committees around the world to give wisdom and guidance to those who sought to further science and plant molecular biology in particular.

Plant science is not renowned for having individuals honored by science and society, but Jeff collected many honors. He was elected to be a Foreign Associate of the US National Academy of Sciences (1985), of the Indian National Science Academy (1998), of the Royal Swedish Academy (1989), and of the Hungarian Academy of Sciences (1993). He won many key prizes, including the Mendel-Medaille of the Deutsche Akademie der Naturforscher Leopoldina (1985), the Otto Bayer-Preis of the Otto-Bayer-Stiftung (1985), Prix Alexandre de Humboldt (1985), the Rank Prize for Nutrition (1987), the IBM Europe Science and Technology Prize (1987), the Wolf Prize in Agriculture (1990), Prix Charles Leopold Mayer of the Academie des Sciences, Paris (1990), the Japan Prize for Biotechnology in Agriculture Sciences by the Science and Technology Foundation of Japan (1998), Premiere Grande Medaille d'Or de l'Academie des Sciences, Paris (1997), the Australia Prize of the Australian Academy of Science (1990), Prix Charles Leopold Mayer of the Academy des Sciences, Paris (1990), the Hansen Gold Medal of the Emil Christian Hansen Foundation, Denmark (1991), and the Wilhelm-Exner-Medaille of Vienna (1995). Several universities awarded him an honorary doctorate degree, including the Hebrew University, Israel (1994), Tel Aviv University, Israel (1997), University of East Anglia, Norwich, United Kingdom (1997), and University Louis Pasteur, Strasbourg (1992). One of his most treasured appointments was of Professeur Honoraire, College de France, Paris (1998).

One cannot look at plant science journals today and their back issues and not recognize that plant science has been transformed since the early 1980s following the activities of those few who believed that crown galls held some valuable biological secrets. Jeff Schell was very much at the helm as he went around the world giving such transforming talks, stimulating so many experiments, writing so many papers, informing politicians and industries, and taking the time here and there to confront "the greens" and skeptics. Two titles of his papers in recent years describe his vision: "Progress in plant science is our best hope to achieve an economically rewarding, sustainable and environmentally stable agriculture" (1995) and "Crop Biotechnology - a necessity for an environmentally friendly and sustainable agriculture" (1995). Let us hope that as we go forward, his vision will be realized.

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