

## COMMENTARY

# The Gatsby Plant Science Summer School: Inspiring the Next Generation of Plant Science Researchers

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**We provide evidence from a 5-year study to show that a single concerted effort at the start of undergraduate study can have a clear and lasting effect on the attitudes of students toward plant science. Attendance at a week-long residential plant science summer school in the first year of an undergraduate degree resulted in many students changing courses to include more plant science and increased numbers of graduates selecting plant-based PhDs. The evidence shows that the Gatsby Plant Science Summer School has increased the pool of high-quality plant science related PhD applicants in the UK and has had a positive impact on students' career aspirations. The results are discussed within the context of enhancing the pipeline of future plant scientists and reversing the decline of this vulnerable and strategically important subject relevant to addressing food security and other major global challenges. We have shown that a single well-designed and timely intervention can influence future student behavior and as such offers a framework of potential use to other vulnerable disciplines.**

## INTRODUCTION

Recent influential publications highlight the importance of plant science in addressing the global challenges of providing sufficient food and sustainable resources for a growing population, all in the face of climate change (OECD, 2009; The Royal Society, 2009; The Government Office for Science London, 2011; Godfray et al., 2010, 2011). Recommendations are made for urgent action, investment, and collaborative international efforts to make step changes in agricultural productivity that are sustainable, as well as in land use policy and practice (Food and Agriculture Organization of the United Nations [FAO], 2009; OECD-FAO, 2009; The Royal Society, 2009; Reganold et al., 2011; UK National Ecosystem Assessment, 2011). Furthermore, recent funding initiatives directed at addressing these global challenges show that there are future employment opportunities in plant science-related research (Biotechnology and Biological Sciences Research Council [BBSRC], 2011a; Global Food Security, 2011). Yet, in Europe and the US, plant science is one of the least popular science subjects at school (Uno, 1994; Hershey, 1996; Jenkins and Pell,

2006; Sjøberg and Schreiner, 2010), and higher education plant science degree courses have for many years failed to attract as many applicants as some other biological disciplines (Sundberg, 2004; Stagg et al., 2009; Jones, 2010; Drea, 2011; The Higher Education Statistics Agency [HESA], 2011). Many students entering biological sciences courses at the college level show little interest in or knowledge of plants, and lecturers perceived that a negative attitude toward plant science is a major inhibitor for the uptake of the subject (Stagg et al., 2009). The term “plant blindness” has been used to suggest a perceptual and visual cognition basis to the apparent lack of awareness and interest in plants that is prevalent among the general population (Wandersee and Schussler, 1999). In a study based on student recall of plant and animal images, Schussler and Olzak (2008) conclude that students have an inherent disparity between their knowledge of animals and plants and recommend that teachers consciously attend to helping students address this imbalance. Educational outreach programs are addressing ways to support teachers in this regard, often through national organizations such as the American Society for Plant Biologists and the recently formed UK Plant Science Federation. However, among the scientific community, there

is concern that a future increase in demand for plant scientists, particularly those with niche skills, may not be met (Stagg et al., 2009; The Royal Society, 2009; Food Research Partnership Skills Sub-Group, 2010). For example, in the Royal Society's landmark study, the working group warned that valuable skills may be lost as researchers and teachers retire and made the recommendation that “Universities should work with funding bodies to reverse the decline in subjects relevant to sustainable intensification of food crop production, such as agronomy, plant physiology, pathology and general botany, soil science, environmental microbiology, weed science and entomology” (The Royal Society, 2009).

To increase the pipeline of plant scientists competent to address the global challenges, it seems necessary to change student attitudes to plants and to consider how the career opportunities that plant science can offer are presented to students.

In 2004, the Gatsby Charitable Foundation extended their support for plant science research by funding a national project aimed at first year undergraduates from 25 UK universities with significant levels of plant science research and teaching. The aim was to inspire students early in their university career through an annual residential summer school and to enable them to develop and consolidate new-found

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interests on return to their home university with continued support from the Gatsby Plant Science Network, their university Gatsby mentor, and other agencies.

In creating the summer school, we wanted to offer students a potentially life-changing experience, one in which they could immerse themselves in plant science for a week and emerge with a different view of plants. We wanted to attract high-achieving and motivated first-year undergraduate students who were receptive to new opportunities but acknowledged that we were unlikely to be successful if there was a financial cost to the student, and we are grateful to the Gatsby Charitable Foundation for fully funding the school. The format for the summer school was developed with the help of the UK plant science research community and support from the Faculty of Biological Sciences, University of Leeds. Key features of the school are described below. Added hidden value of the school is that the plant science research community contributed willingly and provided feedback that the school was a positive experience for them also.

Here, we present the results of a 5-year study that assessed the impact of the Gatsby Plant Science Summer School on student attitudes to plant science and on subsequent changes in their undergraduate study choices, postgraduate study choices, and career aspirations. We discuss the implications of the Gatsby Plant Science Summer School initiative in enhancing the pipeline of plant scientists and in reversing the decline in uptake of this vulnerable and strategically important subject relevant to major global issues, such as sustainable intensification of food crop production and meeting the challenges of climate change.

### THE SUMMER SCHOOL PROGRAM

The summer school takes students selected from 25 universities within the Gatsby Plant Science Network; these are Imperial College London, Royal Holloway University of London, Oxford Brookes University, and the Universities of Bath, Birmingham, Bristol, Cambridge, Durham, East Anglia, Edinburgh, Exeter, Glasgow,

Lancaster, Leeds, Leicester, Liverpool, Manchester, Nottingham, Oxford, Reading, Sheffield, Southampton, St. Andrews, Warwick, and York. The school is aimed at first-year undergraduates, or first and second year for those from Scottish Universities, to allow time for students to consolidate and build on their interest on return to their home university. Universities in the plant science network have significant levels of plant science research and teaching and each has a Gatsby mentor, a plant science professor who selects and mentors their students. The summer school program consists of a series of lectures, tutorials, practical classes, and careers sessions (<http://www.gatsbyplants.leeds.ac.uk/SS>).

Lectures and practicals cover a broad range of exciting, cutting-edge plant science research that addresses globally relevant applied initiatives as well as curiosity-driven research. Examples of lectures from the 2011 school include “The importance of rice to world food security,” Robert Zeigler, Director General, International Rice Research Institute; “Biology to benefit society—the healing power of plants,” Dianna Bowles, Centre for Novel Agricultural Products, University of York; and “Tropical rainforest biodiversity,” Patrick Meir, University of Edinburgh. All lectures are delivered by inspirational research plant scientists who are good communicators to undergraduate students and are filmed and made available online as a teaching tool via the Plant Science Tool for Research-Engaged Education (<http://www.gatsbyplants.leeds.ac.uk/TREE>), which is a shared bank of online lectures, downloadable lecture slides, movies, and other materials on topical plant science to support lecturers in their teaching. It aims to bring inspirational, research-led plant science teaching materials together in a one-stop, easy-to-use website, so that the excitement and potential for plant science can be disseminated to a wide audience of undergraduates through plant science educators worldwide.

Small group tutorials follow the lectures and are led by plant science academics from universities and research establishments around the UK. Following the tutorial, the entire class reconvenes to question the

speaker. This format allows students to focus on the subject of the lecture for 3 h and provides a structure to help them explore the topic, its wider implications, and the extent of current knowledge through questioning.

Five practical investigations in 3-h classes introduce students to the excitement of inquiry and to techniques used in current plant science research. For example, in the plant pathology practical, students explore the local environment for plant pathogens and use modern diagnostic kits to identify them. In the plant development practical, students are introduced to interactive software that allows them to build computational models of flowers and to gain an understanding of the relationship between structure and development. Students are given an opportunity to hone their plant identification skills in lowland heath in the plant identification practical, and in the ecology practical, students use the immediate environment to devise their own experiments to investigate the eco-physiological significance of leaf temperature. The cell biology practical allows the students to explore the secretory pathway in plant cells using confocal laser scanning microscopy, which normally is not available to undergraduate students.

All students take part in a career session in which they meet and talk to successful plant scientists from a range of professions about their own career pathways. The school is held in a retreat-like location with a relaxed atmosphere and limited distractions. The program is intensive, with no formal assessment of student understanding, since the school aims to show students how science works and is communicated. Students are encouraged to identify their interests and passions and to use their remaining undergraduate years to gain related experience. Networking is promoted and emphasis given to building students' confidence.

### Student Selection

Eighty high-achieving end of first year (or mostly second year from Scottish universities) undergraduates are selected from the 25 UK universities in the Gatsby Plant Science Network. Scottish university degrees generally have courses a year longer

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(typically 4 years) than their counterparts elsewhere in the UK. Each university within the Gatsby Plant Science Network has a professor who acts as a mentor to select the most deserving students to attend the summer school and to provide guidance to students for future options. Each university has an allocation of three student places and nominates a reserve list.

### Student Profile

A total of 520 students attended a Gatsby Plant Science Summer School between 2005 and 2010, 69.2% female and 30.8% male. Approximately 80% of students had studied A-levels or equivalent in the state sector. Students were selected on the basis of being high achievers (as assessed by A-grade, A-level results and/or first class first year undergraduate results) and highly motivated (as assessed by the university Gatsby mentor). Degree classification results confirm the assertion that summer school students were high achievers with 53.4% obtaining a first class honors degree and 42.4% an upper second class honors degree ( $n = 118$ ). Summer school students (2006 to 2010 cohorts) were studying for a range of degree programs: 51.6% for biology or biological sciences; 7.8% for natural sciences; 7.0% for ecology or environmental biology or conservation; 6.2% for biochemistry; 6% for plant science or botany; 4.1% for biomedical science; 4.1% for genetics; 3.9% for molecular biology or biotechnology; 3.9% for zoology or animal biology; 1.6% for microbiology; 0.8% for cell biology; 0.5% for chemistry; and 0.3% for each of agriculture, marine biology, pharmacology, neuroscience, psychology, physiology, horticulture, human biology, immunology, and economics.

### Student Surveys

Students attending summer schools from 2005 to 2010 were asked to complete regular surveys (prior to attending a summer school, on leaving the summer school, at two time points during their undergraduate studies and upon graduation), de-

signed to evaluate whether the summer school had changed student attitudes to plant science and changed student practice, namely, undergraduate study choices, postgraduate study choices, and career aspirations. Evidence was gathered from indicators (e.g., study choice of summer school students when compared with a comparison group who had not attended the summer school) and from self-reporting evidence (e.g., whether the students perceived that a change in practice was due to attending the summer school). In addition to quantitative data, all surveys invited comments from the students on the qualitative aspects of the school, which provided insight into the elements responsible for success. The study also investigated the impact of undergraduate vacation research studentships on student postgraduate study choices. The research took place between July 2005 and January 2011, and the surveys may be summarized as follows:

1. Pre-summer school survey: Completed before attending the summer school (data pooled from 2009 to 2010 summer school cohorts;  $n = 133$ , survey response rate=83%). This survey was introduced in 2009.
2. End of summer school survey: Completed on leaving the summer school (data pooled from 2006 to 2010 summer school cohorts,  $n = 374$ , survey response rate = 88%).
3. Second postsummer school survey: At the start of the academic year following the summer school, 3 months after participation, most students were in their second year except for some Scottish students who were in their third year (data pooled from 2006 to 2010 summer school cohorts,  $n = 179$ , survey response rate 42%).
4. Final year survey: Completed during the students' final year of undergraduate study, 1 to 3 years after attending a summer school, depending on whether students were on a 4-year degree program and if they took a placement year (data pooled from 2006 to 2009 summer school cohorts,  $n = 164$ , survey response rate = 47%). Students at-

tending summer school in 2010 had not reached their final year at the time of this survey.

5. Graduate survey: Completed after graduation (2 to 4 years after attending a summer school), data pooled from 2005 to 2008 summer school cohorts  $n = 206$ , survey response rate = 57%; or from 2006 to 2008 summer school cohorts,  $n = 140$ , survey response rate = 53%. The 2005 student cohort graduate data were collected by a short graduate questionnaire with fewer questions than the full graduate survey completed by the 2006 to 2008 cohort. Students attending summer school in 2009 and 2010 had not graduated at the time of this survey, and 57% from the 2008 cohort had graduated at the time of this survey.

### Comparative Data

Comparative data were taken mostly from University of Leeds student data, which was considered appropriate since Leeds is a large UK University, a member of the Russell group of research-intensive universities, and one of the 25 universities within the Gatsby Plant Science Network. Data were gathered from the following sources:

1. A student survey of University of Leeds Bioscience undergraduates, who had not attended a summer school, to assess attitudes to plant science. First-, second-, and third-year bioscience undergraduates from biology (61.3%), biochemistry (18.9%), microbiology (14.2%), and genetics (5.7%) programs of study were surveyed in December 2010 ( $n = 106$ ).
2. University of Leeds undergraduate biology program student data 2008/09 to 2010/11 ( $n = 176$  for 2008/09;  $n = 175$  for 2009/10, and  $n = 174$  for 2010/11) to compare subjects of final year research projects. The Leeds biology program of study offers students the opportunity to complete a plant science-related final year project.
3. University of Leeds PhD students registered in the Faculty of Biological

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Sciences in 2011 ( $n = 221$ ) to compare PhD subject choice. Leeds has one of the leading and largest groups of life science researchers within the UK and supports a wide range of PhD research projects.

- UK BBSRC-funded PhD studentships in biological sciences starting between 2008/09 and 2010/11 ( $n = 1597$ ) to compare PhD subject choice. The BBSRC is the principal public funder of nonmedical biological science (including plant science) research and PhD training in the UK and supported 2348 PhD students in 2009/10 (BBSRC, 2011b).

### DATA ANALYSIS AND RESULTS

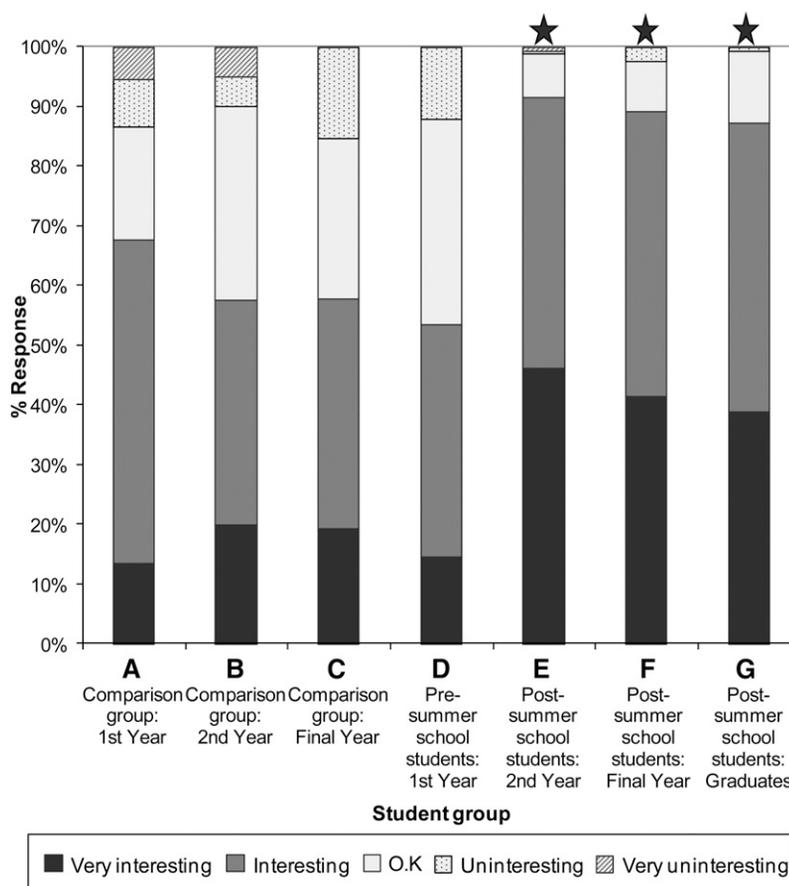
All summer schools between 2005 and 2010 received equally positive student feedback through the “end of summer school surveys” and comparable changes in attitudes to plant science among students’ cohorts were recorded for all summer schools. The authors therefore felt justified in treating all summer schools as equal, and pooled data from different summer school cohorts have been used when discussing the results for simplicity.

### Quantitative Data Analysis

To assess whether the summer school increased student interest in plant science, we asked students to rate their interest before the summer school at two time points during their undergraduate study and after graduation. Data were collected from comparison groups who had not attended a summer school from all undergraduate levels (years 1 to 3) on University of Leeds degree programs in the biosciences area. Responses used to create Figure 1 were given values between 1 and 5 (1 = very uninteresting and 5 = very interesting) and nonparametric statistical methods used to analyze the data. A Kruskal-Wallis test was used to test for significant differences between more than two independent samples, and a Mann-

Whitney test used to test for significant differences between two independent samples. Effect size of Mann-Whitney U test was calculated according to Field (2005), where an absolute value for  $r = 0.1$  is defined as a small effect,  $r = 0.3$  as a medium effect, and  $r = 0.5$  as a large effect.

Figure 1 shows student attitudes to plant science before and at three time points after attending a summer school and those of Leeds University comparison groups (in years 1 to 3) who had not attended a summer school. Before attending a summer school, only 53% of students found plant science interesting or very interesting,



**Figure 1.** Attitudes to Plant Science: How Interesting Do You Find Plant Science?

Interest in plant science among summer school participants before (D) and after (E to G) attending a summer school and among the comparison groups (A to C) who had not attended a summer school. The star indicates significant difference from presummer school data ( $P < 0.001$ ). A to C show comparison group data from University of Leeds Bioscience 2010 undergraduates who had not attended a summer school, in year 1 ( $n = 37$ ), year 2 ( $n = 42$ ), and final year ( $n = 27$ ), respectively. D shows summer school participants before attending a summer school (data pooled from 2009 to 2010 summer school cohorts,  $n = 133$ , response rate = 83%). E shows summer school alumni 3 months after attending a summer school (data pooled from 2006 to 2010 summer school cohorts,  $n = 179$ , response rate = 42%). F shows summer school alumni in their final year (data pooled from 2006 to 2009 summer school cohorts,  $n = 164$ , response rate = 47%). G shows summer school alumni after graduation (data pooled from 2006 to 2008 summer school cohorts,  $n = 140$ , graduate response rate = 53%). Nonparametric statistical methods were used to test for significant differences (Kruskal-Wallis test and Mann-Whitney test).

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but this figure rose significantly ( $P = 0.001$ ) to 92.2, 89.1, and 86.5 among alumni directly after having attended a summer school, in their final year and after graduation. Effect size provides a further measure of the magnitude of the observed effect of the summer school, and large to medium effect sizes ( $r = 0.39$  to  $0.47$ ) were observed among summer school students after attending a summer school when compared with presummer school. Furthermore, before attending a school, the summer school students held a similar opinion of plant science to the comparison group, which would suggest that summer school students were not self-selecting with regards to their perception of plant science prior to attending a summer school. However their "interest in plant science" rose significantly to 92.2 to 89.1% after the summer school, which was significantly higher ( $P = 0.001$ ) than the Leeds University comparison groups from the same year groups, where 57.5 and 55.5% of second-year and final-year students, respectively, found plant science interesting or very interesting. Medium effect sizes of  $r = 0.32$  to  $r = 0.27$  were observed among summer school students after attending a summer school when compared with the comparison groups.

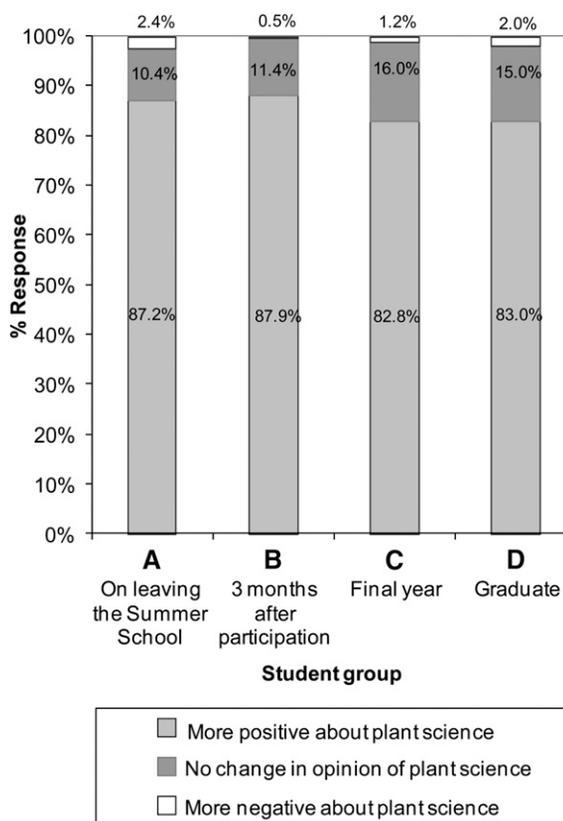
We asked those students attending a school if the summer school changed their overall opinion of plant science. This question principally assessed whether the summer school program introduced students to new ways of using and thinking about plants and against an assumed premise that many students' previous exposure to plant science was comparatively limited and uninspiring (Stagg et al., 2009). Figure 2 shows that 87% students stated that they were more positive about plant science as a result of attending a summer school and that 83% retained this attitude throughout their undergraduate years to graduation.

As evidence for the impact of the summer school on changing student practice, we monitored how many students changed their module choices or final year projects to include more plant science. Figure 3A shows that 62.8% of second year students (or third year for Scottish Univer-

sity students) either changed their modules to include more plant science (17.1%) or their choice of plant science modules had been confirmed (45.7%) as a result of attending a summer school. A similar figure emerged from the responses of final year students, where 63.2% students either changed modules to include plant science (27.1%) or stated that their choice of plant science modules had been confirmed (36.1%) by attendance (Figure 3B). Furthermore, 48% of those who attended a summer school completed a final-year research project with plant science con-

tent, which compares with 19% from 3 years of comparator groups of biology students from the University of Leeds (Figure 4).

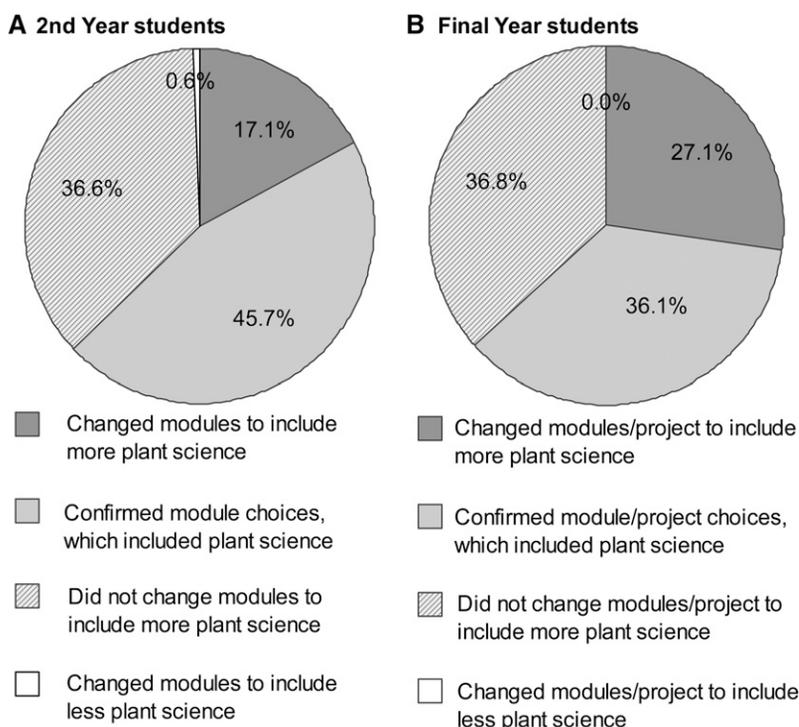
The significant indicator for whether the summer school has added to the pool of plant scientists is given by the numbers of students progressing to PhD study in plant science. Figure 5 shows that 44% of summer school alumni studying for a PhD chose plant science-related projects. This compares with estimates from the BBSRC-funded PhD studentships in biological sciences in which ~12% relate to plant



**Figure 2.** Attitudes to Plant Science: Has the Summer School Changed Your Overall Opinion of Plant Science?

Self-reported influence of the summer school on student attitudes to plant science. Students were asked the question at four different time points following attendance of summer school. For A, on leaving the summer school (data pooled from 2006 to 2010 summer school cohorts,  $n = 374$ , response rate = 88%). For B, 3 months after participation (data pooled from 2006 to 2010 summer school cohorts,  $n = 404$ , response rate = 95%). For C, during the students' final year of undergraduate study (data pooled from 2006 to 2009 summer school cohorts,  $n = 164$ , response rate = 47%). For D, after graduation (data pooled from 2006 to 2008 summer school cohorts,  $n = 147$ , graduate response rate = 55%).

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**Figure 3.** Undergraduate Study Choice: Has the Gatsby Plants Summer School Caused You to Change Your Choice of Modules (and/or Final-Year Project)?

Self-reported influence of the summer school on informing the following: A, second-year study choices (second or third year for Scottish students, data pooled from 2006 to 2010 summer school cohorts,  $n = 175$ , response rate = 41%); B, final-year study choices among summer school alumni, expressed as percentages (data pooled from 2006 to 2009 summer school cohorts,  $n = 155$ , response rate = 45%).

science. The BBSRC, which funds a broad range of nonmedical molecular and cellular bioscience, is the principal public funder of plant science research and PhD training in the UK. University of Leeds Biological Sciences PhD studentships, which include funding from the BBSRC and other agencies, agrees well with the BBSRC figures in that 12% of the total PhDs supported are plant related.

Students were asked if they perceived that the summer school positively influenced their choice of postgraduate study, and 75% of those selecting plant-based PhDs affirmed that it did. Interestingly, 32% of those selecting non-plant science PhD projects also said that the summer school positively influenced their decision to do research. Finally, 58% of graduates responded that the summer school positively influenced their career aspirations (Figure 6).

### Qualitative Assessment

Summer school alumni were asked, through open-ended responses, to define aspects of the summer school that were key to changing their attitudes to plant science. Data were collected from two surveys: a student survey (second postsummer school survey; data pooled from 2006 to 2010 cohorts,  $n = 149$ , response rate = 35%) and a graduate survey (summer school graduates; data pooled from 2006 to 2008 cohorts,  $n = 128$ , response rate = 48%). The responses were analyzed by content analysis to identify key themes of importance in changing student attitudes to plant science. Themes were identified by two researchers independently, to avoid bias, and were based on inference and interpretation of student comments. Two researchers allocated responses to themes independently.

The students and graduates identified similar aspects of the summer school as key in changing their attitude to plant science. Approximately half of all students and graduates identified content and delivery (themes 1 and 2; see below) at the summer school as the most important elements. Both groups also considered future opportunities (career advice) and meeting research scientists who are passionate about their subject and their research (networking) to be important elements of the summer school (themes 3 and 4 below).

### Theme 1. Inspired by Content (i.e., the Importance of Plant Science)

This theme was reflected by 57% of students and 47% of graduates surveyed. Responses included gaining an insight into the world of plant science research, the breadth of the subject, its many possible applications and that it can address many globally important issues. Representative comments included the following:

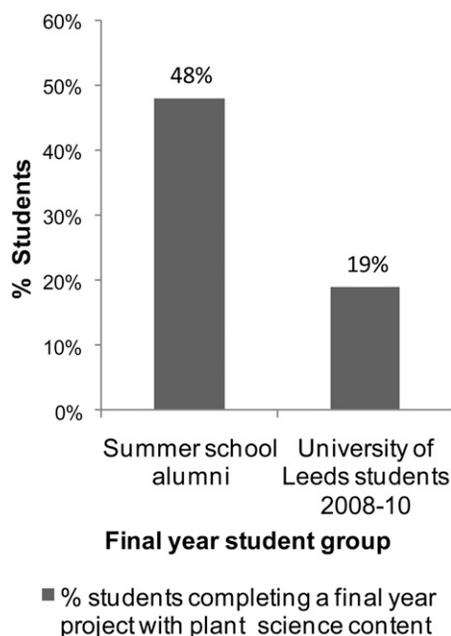
“The informative lectures showed the massive scope plant science has and how integral advancements in it are to the changing world. The practicals led me to consider my natural surroundings in a more logical and scientific way, opening up my eyes to the interactions and patterns prevalent in the environment” (2nd student survey, 2010 alumnus).

“The summer school really highlighted how crucial understanding of plants will be in order to address pressing issues, such as climate change. The stimulating lectures demonstrated how plants are truly fascinating organisms and can truly hold their own against the other kingdoms in terms of interest. I was struck by the enthusiasm of the speakers and the clear love they had for their work” (2nd student survey, 2010 alumnus).

“The summer school opened my mind to plant sciences and made me more determined to pursue a career in this field. I also discovered my interest in plant molecular pathology during the summer school” (graduate survey, 2008 alumnus).

“The inspirational lectures showed me just how varied plant science applications

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**Figure 4.** Undergraduate Final-Year Projects with Plant Science Content.

Percentages of students completing a final-year project with plant science content among summer school alumni (data pooled from 2006 to 2009 summer school cohorts,  $n = 132$ , response rate = 38%) and among comparator groups of University of Leeds Biology undergraduates in 2008/09 to 2010/11 who had not attended a summer school ( $n = 525$ ).

can be and, coupled with the tutorial discussions, made me feel positive and keen to take part in one of these important projects” (2nd student survey, 2010 alumnus).

### **Theme 2. Inspired by Delivery (i.e., Effective Learning Styles)**

This theme was reflected by 54% of students and 57% of graduates surveyed. Responses included the enthusiasm of researchers for the subject and their research; research-based lecture content; the investigative nature of the practicals; use of modern research tools in the practicals and use of plants in the environment; and the tutorials and question and answer session with the speaker, which helped students to learn through questioning and build confidence. Representative comments included the following:

“The practicals allowed a fascinating insight into many different branches of plant biology, which I did not get to that extent as part of my university degree program. In

concert with the lectures and tutorials, they stimulated me to think about a career in plant sciences, and ultimately resulted in my decision to do a PhD in plant sciences” (graduate survey, 2008 alumnus).

“I really enjoyed the practicals; they were an opportunity to get hands on experience of aspects of plant science using techniques outside the scope of my undergraduate course. The lectures were also very interesting” (2nd student survey, 2008 alumnus).

“The practicals were fascinating and the relaxed environment allowed me to take my time and really appreciate what I was learning about. It was also fantastic to be in practicals led by people who were really passionate about their subject; it’s infectious!” (2nd student survey, 2008 alumnus).

“I liked the tutorials because I had the chance to discuss things I did not understand during the lectures and if issues were controversial I was interested in hearing other people’s opinions.” (2nd student survey, 2008 alumnus).

### **Theme 3: Inspired by Future Opportunities (i.e., Career Advice and Research Opportunities)**

This theme was reflected by 18% of students and 20% of graduates surveyed. Representative comments included the following:

“The whole experience of the Gatsby summer school helped me to start to see myself as a future plant scientist, rather than just a university student. Conversations with the profs and PIs who came to give keynote speeches were probably the most important moments” (graduate survey, 2006 alumnus).

“The careers advice was amazing; the careers talk and the postgrad talks were very encouraging and the free time after both the talks where you could easily talk to the people was very beneficial” (2nd student survey, 2010 alumnus).

“Speaking with professionals involved with plant science as I got an idea of the big picture and possible paths for my future” (2nd student survey, 2009 alumnus).

The careers sessions helped me to visualize the different areas of work other than in a university. I now realize I would like to do a PhD.” (2nd student survey, 2009 alumnus).

### **Theme 4: Inspired by People (i.e., Networking)**

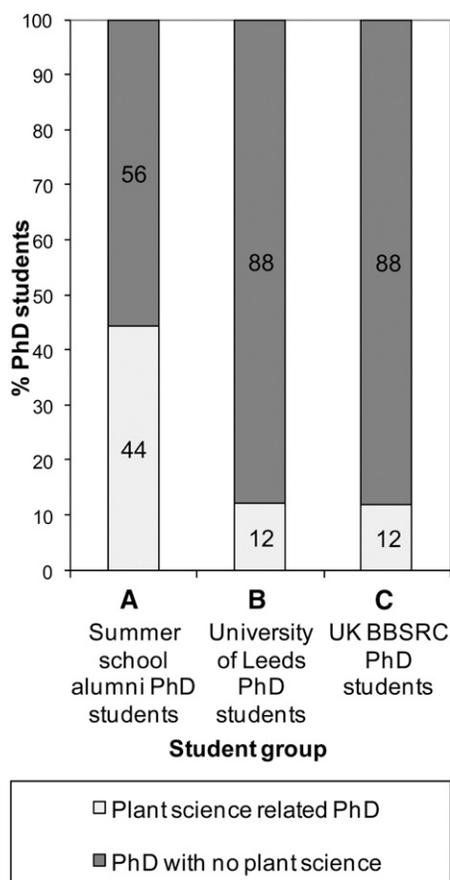
This theme was reflected by 17% of students and 14% of graduates surveyed. Representative comments included the following:

“Meeting and hearing professionals ‘in the field’ helped me to see what life in plant sciences would be like, and that it is more important than we may realize for future generations” (2nd student survey, 2010 alumnus).

“Meeting active plant scientists who were passionate about their field of research. Interacting with other high achieving students, in an environment that was fun, interesting and rewarding” (graduate survey 2008 alumnus).

“The number of people surrounding us that were so passionate about what they do and hearing about what they are doing and why it matters also made plant science seem much more modern and interesting” (2nd student survey, 2008 alumnus).

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**Figure 5.** PhD Subject Choice of Summer School Alumni, University of Leeds, and UK BBSRC PhD Students.

Percentages of PhD students selecting a plant science-related PhD among the following: A, summer school alumni (data pooled from 2005 to 2008 summer school cohorts,  $n = 90$ , survey response rate = 57%); B, PhD students studying at the University of Leeds, Faculty of Biological Sciences in 2011 ( $n = 221$ ); C, UK BBSRC-funded PhD studentships in biological sciences starting between 2008/09 and 2010/11 ( $n = 1597$ ; C. Bhunoo, personal communication). Notes: 100% of 2005 to 2007 summer school cohorts and 57% from 2008 summer school cohort had graduated at time of publication. PhD subject was self-reported by summer school students, identified by the University of Leeds according to the discipline of the supervisor and by the BBSRC based on classification of the studentship abstracts. It is possible that these are underestimates as PhD topics not classified as plant specific may be relevant to plants.

## DISCUSSION

We have shown that, over a period of 4 years, 44% of summer school alumni progressing to PhD study chose plant science projects, when compared with the comparator groups of national BBSRC PhD studentships and University of Leeds PhD studentships, in which only 12% of biological science studentships are plant

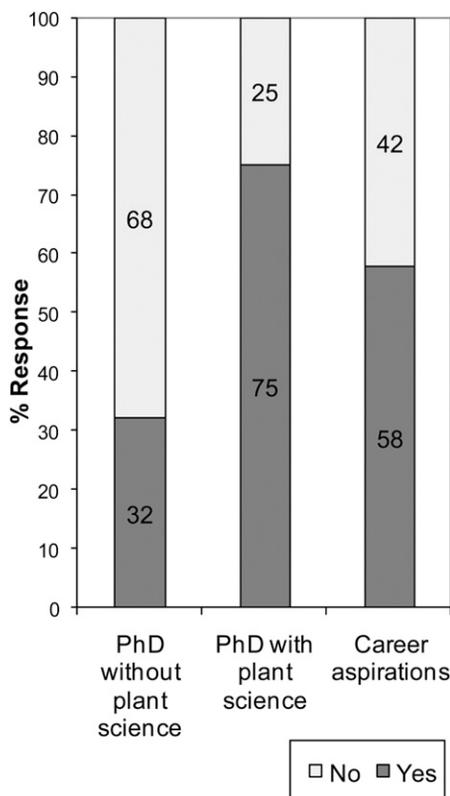
related. The 44% equates to 40 students from the 2005 to 2008 schools, and if this trend continues, we can anticipate that the summer school will contribute around 10 students each year to the pool of plant science PhD researchers.

The BBSRC national statistics indicate that an average of 63 new BBSRC plant science PhDs are funded annually in the UK, some of which are awarded to stu-

dents who have attended the summer school, so the figures are not additive. However, we can infer from our data that the summer school alumni add to the pool of high-quality plant science-related PhD applicants in the UK since 30 of the 40 alumni (i.e., 75%) may not have been inspired to engage in plant science research if they had not attended the summer school in their first year (Figure 6). We argue that there is also likely to be a qualitative benefit from the summer school alumni who, as a consequence of attending the summer school in their first year, have engaged with plant science earlier in their degree program than they might otherwise have done. As a result, they enter the PhD pool equipped with a broader and deeper knowledge base and experience of plants that, we suggest, helps their research to be competitive. It is beyond the scope of this study to measure the impact of the summer school on other professions (e.g., teaching, science communication, policy etc.), but we anticipate that summer school alumni entering these professions will take with them a more positive view of plant science as a result of attending the summer school.

We acknowledge that the success of the school has only been possible with the generosity of the Gatsby Charitable Foundation, and few could adopt the summer school model per se to recruit more plant scientists. However, through the course of this study, we identified certain elements that we believe have been central to the success of the school. First and foremost, delivering a week of plant science teaching early in the degree program is sufficient to significantly and lastingly change student perceptions of plant science. Students were very receptive to the excitement and potential for plant science from inspirational lecturers and enthusiastic tutors, who could convey areas that would be good to work on in the future. Furthermore, they appreciated the careers advice on how to network and use their remaining undergraduate years to gain experience. Students also appreciated use of the environment at the summer school to demonstrate plants in situ as well as the tutorial structure that allowed them to build confidence in questioning.

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**Figure 6.** Postgraduate Study Choice and Career Aspirations of Summer School Alumni: Was Your Choice of Postgraduate Study/Were Your Career Aspirations Influenced by the Summer School?

Self-reported influence of the summer school on informing postgraduate study choice and positively influencing career aspirations among summer school alumni. For A, PhD without plant science (data pooled from 2005 to 2008 cohorts,  $n = 48$ , survey response rate = 57%); for B, PhD with plant science (data pooled from 2005 to 2008 cohorts,  $n = 36$ , survey response rate = 57%); for C, career aspiration respondents (data pooled from 2006 to 2008 cohorts,  $n = 125$ , survey response rate = 53%).

The Gatsby Charitable Foundation and a number of learned societies and other agencies offer vacation research studentships for the penultimate year of study, and we and others have evidence to suggest that these play an important role in maintaining and developing interest. We found that 69% of summer school alumni who chose to study for a PhD in plant science had previously gained undergraduate research experience through a Gatsby Charitable Foundation-funded bursary. Furthermore, 81% of all bursary-funded students stated that the experience had influenced their career aspirations. These data suggest that a positive undergraduate research experience has a significant impact on students

choosing to pursue a research career in plant science and supports other studies documenting undergraduate research placement programs (Balster et al., 2010; BBSRC, 2010).

Recent educational studies provide experimental evidence in support of programs that increase student interest in plants (Strgar, 2007) and promote undergraduate interest and confidence in research (Balster et al., 2010). These reports and our findings highlight the importance of exposing students, at all levels, to knowledgeable and enthusiastic teachers. If we are to correct plant blindness, concerted collaborative efforts will continue to be needed between plant science researchers and teachers. It

is difficult to assign a cost to such initiatives but our experience from this program is that it is important to be able to attract and support inspirational ideas from enthusiastic experts that will resonate with students.

We offer an optimistic view. The scale of global issues that confront us needs well-qualified plant scientists, and record levels of undergraduates are now entering higher education expectant of purposeful future employment. The evidence in this article suggests that, if plant science is introduced in a sufficiently prominent and engaging way from the first year of an undergraduate program, then it is possible to change attitudes to plant science among the current UK undergraduate population and to inspire the next generation of researchers to consider plant science as a career option.

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## AUTHOR CONTRIBUTIONS

All authors worked as a team to develop and run the summer schools. The student surveys were designed and compiled by all authors. Data were collected by A.L. and J.J. and analyzed by A.L. with input from J.J. A.L. and C.K. wrote the article. Individual roles are as follows: A.L., Project Officer (2005 to present); J.J., Project Officer (2006 to 2010); C.K., Project Coordinator (2004 to present).

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**The Gatsby Plant Science Summer School: Inspiring the Next Generation of Plant Science Researchers**

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