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Bibliometric analysis of biotechnology research in Pakistan

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Abstract In this study we present an analysis of the research trends in Pakistan in the field of biotechnology for the period 1980–2011. Starting with just 15 publications in 1980 with a negligible annual growth rate for the initial 15 years, the number of publications reached 3,273 in 2011 with an annual growth rate of 22 % for the last 15 years. This growth in publications is studied through factors such as Relative Growth Rate and Doubling Time. A comparison of organizations actively engaged in research in biotechnology is made through factors such as their total publications, total citations, and average citations per paper and indices that determine the quality of publications like *h*-index, *g*-index, *hg*-index and *p*-index. University of Karachi shows the highest number of publications (2,698), while National Institute of Biotechnology and Genetic Engineering with fewer publications shows the highest average citation per paper (8.07). Agha Khan University however, shows the highest *h*, *g*, *hg* and *p* indices.

Keywords Biotechnology · Bibliometric · Scientometric · Pakistan

Introduction

According to the Organization for Economic Cooperation and Development (OECD) biotechnology can be defined as the application of science and technology to living organisms as well as parts, products and models thereof to alter living or non living materials for the production of knowledge, goods and services (OECD 2001). This definition is all encompassing and covers all modern biotechnology like gene cloning, recombinant DNA, etc. as well as traditional biotechnology methods like plant and animal breeding, etc.

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The roots of modern biotechnology in Pakistan can be traced back to the establishment of Centre of Excellence in Molecular Biology (CEMB) at University of Punjab in 1986 followed by the establishment of Centre for Applied Molecular Biology (1987) also at the same university and National Institute for Biotechnology and Genetic Engineering (NIBGE) in 1992 under the umbrella of Pakistan Atomic Energy Commission. The 90s also saw the establishment of centers dedicated to biotechnology within the existing research organizations and universities. Some of the important ones include Biomedical and Genetic Engineering Division at A.Q. Khan Research Labs, Biotechnology and Food Research Centre at Pakistan Council for Scientific and Industrial Research (PCSIR) and Agricultural Biotechnology Institute at National Agricultural Research Centre (NARC). Special institutes or faculties were also created within various universities to produce manpower in the field of biotechnology (Pakissan 2007).

Another milestone in the development of biotechnology in Pakistan was the creation of National Biotechnology Commission in 2003. One of the major achievements of this Commission was the formulation and adaptation of bio-safety rules in the country (Rules 2005). The Commission also played a major role in better coordinating the research by country's 26 biotechnology and genetic engineering institutions. Unfortunately the Commission ceased to exist after 2008 due to change in priorities of the government.

The initial research in biotechnology during the 80s focused mainly on the introduction of Bt cotton in the country; however, with time the scope of research has widened to include many other fields primarily in the domain of agriculture and medical sciences.

Methodology

The data for bibliometric analysis in this study is retrieved from world's highest international multi-disciplinary abstract and indexing database Scopus, covering about 15,000 sources. Scopus was launched in 2004 and earned high repute in bibliometric assessment study in multi-disciplinary research areas. A number of studies have analyzed the coverage difference between Scopus and other databases such as WoS, Google Scholar, Ulrich's International Periodical Directory and CSA Illumina (Archambault et al. 2009; López-Illescas et al. 2009). Norris analyzed differences in these databases and concluded their study with following remarks, "Scopus offers the best coverage from amongst these databases and could be used as an alternative to the Web of Science as a tool to evaluate the research impact in the social sciences" (Norris and Oppenheim 2007).

A number of studies have been carried out by using bibliometric data analysis techniques to present an overview of the growth of emerging scientific fields (Braun et al. 1997; Gupta 2009; Zhu and Willett 2011; Bajwa and Yaldram 2012). In the present study we have explored various aspects of the growth of research in the field of biotechnology in Pakistan. In particular we have studied factors like (1) Growth in publications as measured by the Relative Growth Rate (RGR) and Doubling Time (D_t), (2) Productivity and quantification of research output for different institutions of the country as determined by the indices like *h*-index, *g*-index, *hg*-index and *p*-index.

A broad search was carried out using keyword bio* for the period 1980–2011. The initial output data that was retrieved was cleaned by removing irrelevant and repeated records. Journals with zero impact factor were also removed from the record. Finally 18,085 publications were considered for further analysis in Table 1.

Table 1 Abbreviations used in the text

S. no.	Abbreviations	List of major institutions
1	AKU	The Aga Khan University
2	ARID	University of Arid Agriculture, Rawalpindi
3	BZU	Bahauddin Zakariya University
4	CIIT	COMSATS Institute of Information Technology
5	GCU	Government College University, Lahore
6	IUB	Islamia University, Bahawalpur
7	NARC	National Agricultural Research Centre
8	NIAB	Nuclear Institute for Agriculture and Biology, Pakistan
9	NIBGE	National Institute for Biotechnology and Genetic Engineering, Pakistan
10	NUST	National University of Sciences and Technology, Pakistan
11	NWFPAU	NWFP Agricultural University
12	PCSIR	Pakistan Council of Scientific and Industrial Research
13	PINSTECH	Pakistan Institute of Nuclear Science and Technology
14	PU	University of Punjab, Lahore
15	QAU	Quaid-i-Azam University
16	UAF	University of Agriculture, Faisalabad
17	UoK	University of Karachi
18	UoP	University of Peshawar
19	UoS	University of Sargodha
20	USindh	University of Sindh
21	RGR	Relative growth rate
22	D_t	Doubling time
23	TP	Total publications
24	TC	Total citations
25	ACPP	Average citation per paper

Preferred journals and areas of research

We have covered the period 1980–2011 (30 years) for this study. A total number of 18,085 publications appeared in 155 journals. Of these publications 689 were in the form of conference proceedings and another 129 in the form of book series. Of the total publications, almost 25 % appeared in local Pakistani journals (all with a positive impact factor). A list of top 20 journals, preferred by Pakistani researchers is given in Table 2. In order to assess the quality of these publications in Table 3 we show the number of publications appearing in journals starting with impact factors lying between 10 and 9 and going down to number of publications with impact factors lying between 1 and 0.

The number of research publications in different areas of biotechnology is listed in Table 4. Pakistan is an agricultural country whose economy is dominated by this sector. Cotton is a major export item followed by citrus fruit. It is therefore normal to expect research in biotechnology to be dominated by the agricultural sector. 23 % of the total publications are in this field, followed by medicine (16 %), chemistry (14 %) and biochemistry, genetics and molecular biology (12 %). The research in medicine is predominately concerned with medicinal properties of plants. The classification of subjects is based on the one provided by Scopus.

Table 2 Top 20 journals according to the number of publications

S. no.	Journal	No. of publications	Impact factor (2011)
1	Pakistan Journal of Botany	1,710	0.836
2	Journal of the College of Physicians and Surgeons Pakistan	935	0.34
3	Journal of the Chemical Society of Pakistan	790	1.377
4	Pakistan Journal of Zoology	752	0.338
5	Acta Crystallographica Section e Structure Reports Online	709	0.41
6	African Journal of Biotechnology	448	0.57
7	Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics	208	0.42
8	Pakistan Journal of Medical Sciences	198	0.161
9	Asian Journal of Chemistry	142	0.266
10	Journal of Medical Plant Research	131	0.59
11	Natural Product Research	115	1.009
12	Journal of Hazardous Materials	106	4.173
13	Journal of Enzyme Inhibition and Medicinal Chemistry	100	1.617
14	Virology Journal	87	2.343
15	Pakistan Journal of Pharmaceutical Sciences	86	1.103
16	Journal of Radioanalytical and Nuclear Chemistry	85	1.52
17	Pakistan Veterinary Journal	82	1.255
18	Biological Trace Element Research	70	1.923
19	Biochemical Society Transactions	66	3.711
20	Phytochemistry	65	3.351

Table 3 The number of publications appearing in high impact factor journals

S. no.	Journal impact factor range	No. of publications
1	10–8	9
2	8–6	0
3	6–4	163
4	4–2	631
5	2–0	17,282

Growth of publications

The growth in the number of publications is measured by means of two related parameters viz. RGR and D_t (Mahapatra 1985).

RGR in classical growth analysis is defined as:

$$\text{RGR} = (\ln N_2 - \ln N_1)/(t_2 - t_1)$$

Here N_2 and N_1 are the cumulative publications in 2 years t_2 and t_1. In the present analysis $t_2 - t_1$ is taken as 1 year. RGR can then be expressed as $\text{RGR} = \ln (N_2/N_1)$.

The D_t is the time required for publications to double in number for a given RGR. D_t is expressed as:

Table 4 Subject wise distribution of publications in biotechnology

S. no.	Subject	No. of publications	% of total
1	Agricultural and biological sciences	4,105	22.70
2	Medicine	2,969	16.42
3	Chemistry	2,582	14.28
4	Biochemistry, genetics and molecular biology	2,210	12.22
5	Pharmacology, toxicology and pharmaceutics	1,160	6.41
6	Immunology and microbiology	966	5.34
7	Physics and astronomy	791	4.37
8	Environmental science	729	4.03
9	Materials science	685	3.79
10	Engineering	501	2.77
11	Chemical engineering	471	2.60
12	Computer science	413	2.28
13	Veterinary	233	1.29
14	Neuroscience	106	0.59
15	Multidisciplinary	71	0.39
16	Health professions	55	0.30
17	Psychology	20	0.11
18	Dentistry	18	0.10
		18,085	100.00

$$D_t = (t_2 - t_1)\ \ln 2/(\ln N_2 - \ln N_1) \text{ or } D_t = \ln 2/\text{RGR}$$

A constant value for RGR in each subsequent year is an indication that the growth rate is exponential. The D_t is a characteristic time for this exponential growth. In Table 5 we have represented year wise number of publications in the field of biotechnology, their cumulative number, RGR and D_t for the period 1980–2011. Starting from just 15 publications in 1980 the period 1980–1995 (15 years) does not show any significant rise in the number of publications. Although the number has more than tripled over this period, not much significance can be attached to these numbers as the overall number remains low. However, in 1996 there is a 5.5 fold increase in the number of publications. Looking at the publications of different organization the same jump is seen for each one of them. This jump therefore cannot be attributed to an increased output from any organization. We then analyzed the data generated by Scopus. We realized that Scopus had included the top Pakistani research journal, i.e., Pakistan Journal of Botany in its data base in the year 1996 and the following two journals viz. Journal of the College of Physicians and Surgeons Pakistan and Journal of the Chemical Society of Pakistan in the year 1997. The inclusion of these journals is reflected in the sudden jump in the number of publications for the year 1996. The RGR settles down to an average value of 0.21 and an average D_t of 3.4 for the last 15 years. The growth rate of publications (Fig. 1a) during the last 15 years (1997–2011) is an impressive 22 %.

Quality of publications

The number of citations that a paper receives is a good measure of its quality and importance. In columns six and seven of Table 5 we give the number of citations that a

Table 5 Pakistan's research output, relative growth rate, doubling time and citations in the field of biotechnology

Years	No. of publications	Cumulative	RGR	D_t	Citation	Citation per paper
1980	15	15			0	0
1981	12	27	0.59	1.18	0	0
1982	12	39	0.37	1.88	0	0
1983	11	50	0.25	2.79	0	0
1984	21	71	0.35	1.98	0	0
1985	13	84	0.17	4.12	0	0
1986	23	107	0.24	2.86	0	0
1987	31	138	0.25	2.72	0	0
1988	36	174	0.23	2.99	0	0
1989	31	205	0.16	4.23	0	0
1990	46	251	0.20	3.42	0	0
1991	31	282	0.12	5.95	0	0
1992	35	317	0.12	5.92	0	0
1993	51	368	0.15	4.65	2	0.04
1994	57	425	0.14	4.81	0	0
1995	52	477	0.12	6.01	1	0.02
1996	281	758	0.46	1.50	255	0.91
1997	339	1,097	0.37	1.88	413	1.22
1998	332	1,429	0.26	2.62	510	1.54
1999	346	1,775	0.22	3.20	732	2.12
2000	316	2,091	0.16	4.23	946	2.99
2001	342	2,433	0.15	4.58	1,229	3.59
2002	470	2,903	0.18	3.92	1,666	3.54
2003	565	3,468	0.18	3.90	1,980	3.50
2004	670	4,138	0.18	3.92	2,443	3.65
2005	877	5,015	0.19	3.61	3,479	3.97
2006	1,253	6,268	0.22	3.11	4,621	3.69
2007	1,515	7,783	0.22	3.20	6,218	4.10
2008	1,852	9,635	0.21	3.25	8,761	4.73
2009	2,297	11,932	0.21	3.24	12,387	5.39
2010	2,880	14,812	0.22	3.21	17,046	5.92
2011	3,273	18,085	0.20	3.47	22,671	6.93

paper has received for that year and the average citations per paper (ACCP), respectively. The citations already reported in a certain year are not included in the subsequent year. Figure 1b shows the growth trend in the number of citations. For the period 1980–1995 the number of publications in biotechnology is low with hardly any citations. The year 1996 shows a sudden jump in the number of publications from 52 to 281. The reason for this sudden jump is already explained in the previous section. As pointed out earlier the 90s saw the establishment of a number of high quality institutes in biotechnology. Their effect on the number of publications and also on their quality is quite evident. From 1996 onward,

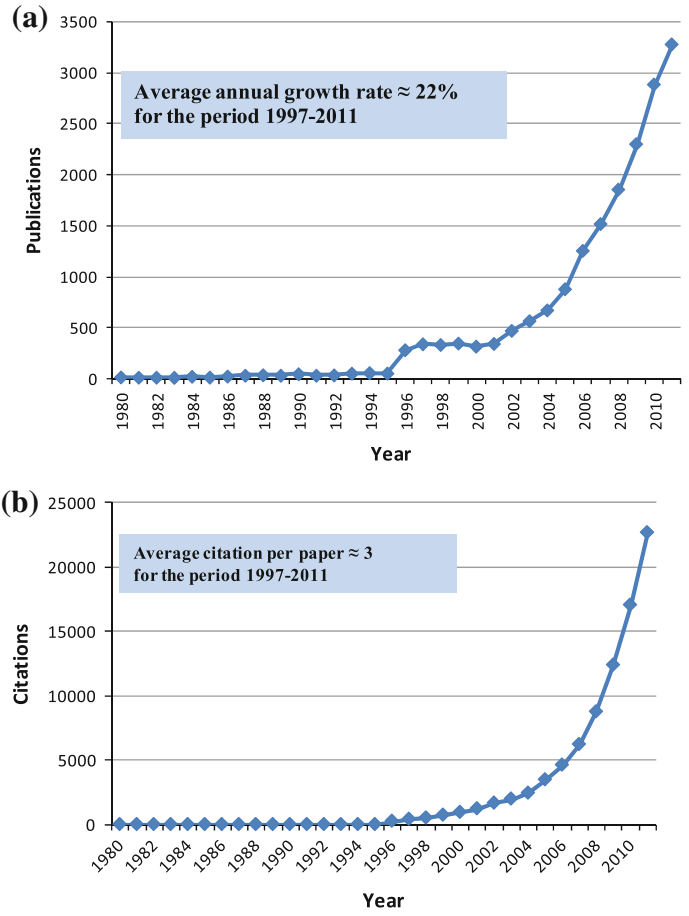


Fig. 1 **a** Publications in biotechnology for period 1980–2011. **b** Total citations of published papers during 1980–2011

we see a consistent rise in the number of citations. The ACPP is about three for the period 1997–2011. ACPP also shows a rising trend, increasing from 0.9 in 1996 to 6.5 in 2011.

ACPP is not the only criterion for determining the quality and impact of a publication. Several other indices have been defined to assess the productivity and quality of publications of an organization, laboratory or an individual. Each of these indexes has its advantages and disadvantages. Some of these are discussed below.

h-index

This index was first proposed by Hirsch. If N_p is the number of publications emanating from an institute or an individual for a certain period of time then the institute or individual has an index h, if h of his publications has at least h citations each. The h-index is insensitive to both the highly cited publications and publications with low citations. The former is a disadvantage while the later is an advantage of the h-index (Hirsch 2005).

g-index

Egghe introduced the *g*-index that accounts for the drawbacks of the *h*-index (Egghe 2006). Publications have a *g*-index if *g* is the highest rank such that top *g* papers have together at least g^2 citations. The *g*-index can give undue advantage to a single highly cited publication as compared to several publications with a consistently moderate number of citations.

hg-index

This index was proposed by Alonson et al. (2010). This is simply given by:

$$hg = (h \times g)^{1/2}$$

This index minimizes the disadvantages of both the *h* and *g* indices.

p-index

This index was proposed by Prathap (2010) and is defined as.

$$p = [C \cdot (C/P)]^{1/3}$$

Here *C* is the total number of citations for *P* publications. This index gives a good balance between quality (*C*/*P*) and quantity *C*.

In Table 6 we present the total publications (TP), total citations (TC), ACPP, and the four indices, the *h*-index, *g*-index, *hg*-index and *p*-index for the top 20 institutions of the country with publications in biotechnology for the period 1980–2011.

University of Karachi (UoK) stands at the top of the table. The university has seven very active centers contributing towards this field. These are Dr. Punjwani Centre for Molecular Medicine and Drug Research, H.E.J Institute, Dr. A.Q. Khan Institute of Biotechnology and Genetic Engineering, Centre for Molecular Genetics, Department of Biotechnology, Department of Microbiology and Department of Genetics.

The Quaid-i-Azam University is at number two regarding the number of publications. The University is the top university of the country in natural sciences, according to the ranking determined by the Higher Education Commission (HEC) (Pakimag 2012). Most of the research in biotechnology is being carried out at the Department of Biological Sciences and Department of Chemistry.

Agha Khan University (AKU) is the foremost private medical university of the country. It has also been ranked as the leading medical university of the country by HEC (2010). It stands at number three regarding the total number of publications. Its publications are all in medical sciences.

Fourth and fifth on the publication list are University of Agriculture, Faisalabad (UAF) and Punjab University (PU), respectively with a difference of just 15 publications between them. As the name suggests UAF is entirely concerned with the agricultural sector and has been ranked as the number one agricultural university of the country (16), while PU is a general purpose university. PU has associated with it the CEMB, Centre for Applied Molecular Biology, School of Biological Sciences, Institute of Biochemistry and Biotechnology and Department of Microbiology and Molecular Genetics.

Although, NIBGE is 13th on the publication list, but it shows the highest ACPP of 8.07. However, if we look at the other factors determining the quality of publications then AKU shows the highest *h*, *g*, *hg* and *p* indices. We must add a note of caution here. The impact

Table 6 Contribution of top 20 Pakistani institutions towards publications, citations and various indices in the field of biotechnology

S. no.	Institution	TP	TC	ACPP	*h*-index	*g*-index	*hg*-index	*p*-index
1	UoK	2,698	10,326	3.83	16	101	40.20	34.06
2	QAU	1,788	6,972	3.90	16	83	36.44	30.06
3	AKU	1,523	12,031	7.90	16	109	41.76	45.63
4	UAF	1,463	6,668	4.56	16	81	36.00	31.20
5	PU	1,448	4,619	3.19	16	67	32.74	24.51
6	GCU	744	1,663	2.24	10	13	11.40	15.49
7	BZU	639	2,801	4.38	15	52	27.93	23.06
8	UoP	592	2,192	3.43	12	46	23.49	20.09
9	NIAB	561	1,936	3.27	16	43	26.23	18.83
10	USindh	544	2,153	3.84	10	46	21.45	20.42
11	NARC	539	1,880	3.46	13	43	23.64	18.71
12	UoS	523	905	1.68	5	30	12.25	11.61
13	NIBGE	507	4,221	8.07	15	64	30.98	32.75
14	PCSIR	462	1,328	2.62	11	36	19.90	15.62
15	ARID	419	990	2.14	7	31	14.73	13.27
16	IUB	389	1,169	2.79	12	34	20.20	15.20
17	CIIT	384	1,406	3.61	6	37	14.90	17.26
18	NUST	319	625	1.63	6	25	12.25	10.69
19	NWFPAU	291	1,125	3.53	11	33	19.05	16.32
20	PINSTECH	247	1,709	5.87	12	41	22.18	22.78

factor of a journal has a very strong correlation with the scientific discipline under consideration. Medical journals usually tend to have a high impact factor and consequently higher citation counts than other journals. Institutions like AKU, where research is primarily related to the medical sciences therefore have a relative advantage as compared to other institutions.

There can be several factors that can influence the quality and quantity of publications of any institution, important among these being funding and manpower. As mentioned above, UoK has seven institutions engaged in the field of biotechnology, some of these being internationally recognized. It is therefore entirely understandable that the university has the highest number of publications. On the other hand, QAU with far fewer researchers is not far behind UoK in the number of publications, because of a higher quality of manpower. For each institution one has to weigh quantity versus quality of manpower to arrive at some reasonable conclusion.

As far as funding is concerned, the primary source for all public sector research institutions and universities is the government of Pakistan (for recurrent cost). However, for carrying out research projects every institution depends upon external sources, which includes, the Planning Commission of Pakistan, Pakistan Academy of sciences, Pakistan Science Foundation, Higher Education Commission, Islamic Development Bank, European Union, World Bank, USAID, Rockefeller Foundation, Australian Centre for International Agriculture Research, etc. It is difficult to get exact funding figures for each institution, but one can safely conjecture that some of the top research institutions and universities are able to generate enough funding from these sources.

Collaboration with foreign partners

Figure 2 represents the distribution of number of publications involving collaboration with foreign partners.

The total number of these publications is 11,198 which is almost 62 % of the total. Various institutes have collaborative projects with foreign counterparts. Another contributing factor is the research being conducted by Pakistani researchers in foreign laboratories under a scheme initiated by the HEC. Under this scheme more than 4,000 scholarships were awarded by HEC during the period 2003–2010 to students to pursue PhD studies abroad (HEC 2010). HEC has also initiated other schemes for encouraging foreign collaboration like awarding pot doctoral fellowships and inviting foreign professors to the country.

Some recent advances in biotechnology in the country

Some of the more notable achievements of Pakistani scientists in the field of Biotechnology in the last few years are enumerated below:

(1) The complete gene mapping sequence of a Pakistani citizen has been accomplished by the Punjwani Centre for Molecular Medicine and Drug Research (a component of Karachi University). Pakistan has thus joined the short list of nations that has accomplished this job (SciDev 2011).

(2) Thomson Reuters Science Watch produces a bimonthly listing of the scientists, institutions, countries and journals that have achieved the highest percentage increase in total citations for this period. These entries are singled out as Rising Stars in their respective fields. Pakistan has been a Science Watch (ScienceWatch 2012) rising star for several years for research in biological sciences.

(3) Pakistan began producing biotechnology based pharmaceuticals in 2009. The first of these plants was set up to produce interferon for treatment of hepatitis (Aldridge 2009).

(4) In May 2010 eight Bt cotton varieties were approved by the government of Pakistan for general cultivation (GainReport 2010).

(5) With 2.6 million hectares of Bt cotton planted in 2011, Pakistan ranks 8th in the world in terms of the area for biotech crops. Mainly due to the introduction of Bt cotton Pakistan has had a bumper of cotton in 2011–2012 (Haq 2012).

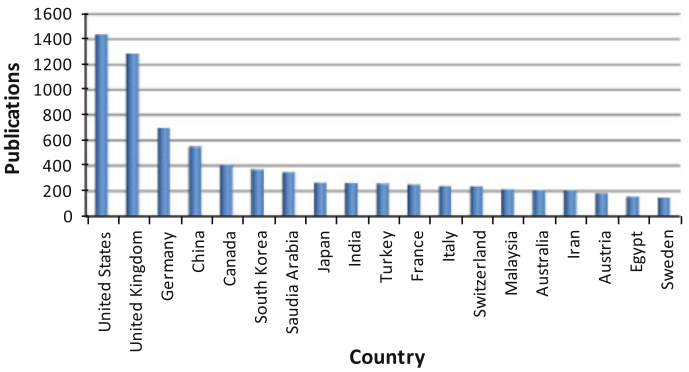


Fig. 2 Research publications with foreign collaboration

Table 7 Status of genetically modified crops in Pakistan

GM crop	Genetically engineered traits	Stage
Cotton	Insect resistance with biotech and other genes, virus resistance, salinity tolerance, fiber modification, drought, herbicide tolerance	Experimental/field trials/ready for release
Rice	Bacterial blight resistance, insect resistance	Field trial/ready for release
Corn	Drought, herbicide and insect resistance	Experimental
Potato	Virus resistance, salt tolerance, insect resistance	Experimental
Sugarcane	Insect resistance	Experimental
Sunflower	Drought and herbicide resistance	Experimental
Chilies	Virus resistance	Experimental
Tomato	Virus resistance, male sterility, salinity tolerance	Experimental
Cucurbits	Virus resistance	Experimental
Tobacco	Virus resistance	Experimental
Groundnut	Fungal resistance, herbicide tolerance	Experimental

Table 8 Patents registered with international and national agencies

Discipline	International	National
Agricultural sciences	14	11
Health sciences	3	0
Biological sciences	10	7
Total	27	18

Source (PCST 2011)

(6) A reported 36 cases of GM crops have been submitted to the National Biosafety Committee, of these 26 have been notified by the Environmental Protection Agency for laboratory testing. Table 7 presents the overall situation of GM crop in the country (GainReport 2010).

(7) There is evidence to the fact that the universities and R&D institutes of the country have stepped up their research efforts in biotechnology due mainly to the reforms introduced by HEC; however, translating these research efforts into visible benefits for the society is still a major challenge. The number of patents registered internationally and nationally in different disciplines is shown in Table 8. It is expected that these numbers will increase significantly as the government now offers financial incentives not only for research publications, but also for patents registered with national and international agencies.

Conclusion

Research in the field of biotechnology started around the year 1980 in Pakistan. Ever since, then the number of research publications in this field has shown a rising trend. From just 15 publications in 1980 the number increased to 3,273 for 2011. Majority of these publications (22 % of total) are related to agricultural and biological sciences, followed by medicine (16 %), chemistry (14 %) and biochemistry/genetics/molecular biology (12 %).

The concentration of research is mainly in the universities. Among the top 20 institutions contributing towards research in biotechnology, 15 are universities and the remaining five are R&D organizations. 62 % of the publications have foreign collaborators associated with them.

University of Karachi has the maximum number of publications (2,698), although NIBGE and AKU with ACPP of 8.07 and 7.90 show a much better quality of publications. The same conclusion can also be drawn by considering other indices like the *h*-index, *g*-index, *hg*-index and *p*-index. The rise in the number of publications can be associated with the establishment of a number of dedicated centers in biotechnology combined with a well coordinated science and technology policy of the government during the period 2000–2010. The establishment of Biotechnology Commission during this period also had a very positive effect.

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