
Assessing quality, content, and accessibility of web information about plant biotechnology

Barbara M. Zawedde

Graduate Programme in Plant Breeding,
Genetics and Biotechnology,
Plant and Soil Sciences Building,
Michigan State University,
East Lansing, MI 48824, USA
E-mail: zawedde@msu.edu

Suneth S. Sooriyapathirana

Department of Molecular Biology and Biotechnology,
Faculty of Science,
University of Peradeniya,
Peradeniya 20400, Sri Lanka
E-mail: sooriyap@pdn.ac.lk

**Patrick J. Bigelow, James F. Hancock and
Rebecca Grumet***

Graduate Programme in Plant Breeding,
Genetics and Biotechnology,
Plant and Soil Sciences Building,
Michigan State University,
East Lansing, MI 48824, USA
E-mail: bigelowp@msu.edu
E-mail: hancock@msu.edu
E-mail: grumet@msu.edu
*Corresponding author

Abstract: The ability to obtain reliable information is critical for decision makers. We examined sources of information about plant biotechnology available on the internet to identify credible, high calibre websites. Google-based searches were performed using: 'plant biotechnology', 'plant genetic engineering', 'genetically modified organisms', 'GMO', 'living modified organisms' and 'LMO'. Lists of websites retrieved, frequency of use, and audience varied greatly depending on keyword. Quality of content as assessed by frequency of updates, subject depth, declaration of authorship, indication of source of information, credibility of source, and neutrality, differed significantly among websites. The majority of high quality sites had government, academic, or research affiliations, however these were less frequently retrieved among the top listed websites. To ensure accurate public awareness about plant biotechnology it is important that high quality sites are recommended by information providers, and that they utilise terminology most frequently used by the public.

Keywords: genetically modified organisms; GMO; living modified organisms; LMO; plant biotechnology; plant genetic engineering; internet search; key words; biotechnology; Google search; web information.

Reference to this paper should be made as follows: Zawedde, B.M., Sooriyapathirana, S.S., Bigelow, P.J., Hancock, J.F. and Grumet, R. (2012) 'Assessing quality, content, and accessibility of web information about plant biotechnology', *Int. J. Biotechnology*, Vol. 12, No. 3, pp.198–223.

Biographical notes: Barbara M. Zawedde is a graduate student in the Programme in Plant Breeding, Genetics and Biotechnology at Michigan State University. Her dissertation research deals with environmental biosafety concerns and communication in East Africa and sweet potato germplasm diversity. She was previously a research assistant with the International Food Policy Institute (IFPRI) under the Programme for Biosafety Systems in Kampala, Uganda.

Suneth S. Sooriyapathirana is a member of the Faculty of Science in the Department of Molecular Biology and Biotechnology in the University of Peradeniya in Sri Lanka. His research interests focus on dissection of genes underlying complex traits and biotechnology applications. He has published in the area of quantitative trait analysis using molecular markers.

Patrick J. Bigelow is a graduate student in the Programme in Plant Breeding, Genetics and Biotechnology at Michigan State University. His dissertation research deals with environmental risk assessment associated with transgenes conferring resistance to abiotic stresses.

James F. Hancock is a University Distinguished Professor and the Director of the Plant Biotechnology Resource and Outreach Centre at Michigan State University. He has published widely on gene flow issues associated with genetically engineered crops and authored a book entitled *Plant Evolution and the Origin of Crop Species*. He has served on expert panels on environmental biosafety hosted by Entomological Society of America, FAO, Pew Foundation, the Union of Concerned Scientists and USDA-APHIS. He has also been an active participant in USAID PBS-sponsored workshops on environmental biosafety in several countries including South Africa, Tanzania, Uganda and the USA. He currently serves as a resource person for the African Biosafety Network of Expertise (ABNE) supported by the Bill and Melinda Gates Foundation.

Rebecca Grumet is a Professor in the Department of Horticulture and the Graduate Programmes in Genetics, and Plant Breeding, Genetics and Biotechnology at Michigan State University. She has published extensively in the area of plant biotechnology and risk assessment for transgenic crops and was the Lead Editor for the book, *Environmental Safety of Genetically Engineered Crops* (2011). She is a coorganiser of the International Short Course in Environmental Aspects of Agricultural Biotechnology at MSU, serves as a resource person for the African Biosafety Network of Expertise (ABNE), has participated in several national workshops examining crop biotechnology biosafety, and has been as a member of the Institutional Biosafety Committee at MSU since 1995.

1 Introduction

Importance of the internet continues to grow as a primary source of information. More than two billion users, an estimated 30% of the world population, made use of the internet in 2011 (Internet World Stats, 2011). This unparalleled source of information now available at virtually any location creates tremendous opportunities to improve communication and inform decision making, but can also generate many problems with respect to reliability and accuracy of the information. The methods used to collect information can greatly influence results obtained (Spink and Cole, 2001). The quality and credibility of the website accessed can affect the type of information that people receive and use to make decisions on topics of personal, professional, and civic importance. Credibility of information obtained from the internet has become a particularly important question, since there is no required formal review process of content before posting on the web (Perez-Lopez and Perez-Roncero, 2006). As a result, making judgments regarding information credibility becomes a challenging task for most users, especially about controversial topics such as genetically modified organisms (GMO).

Production of GM crops has grown to an estimated 148 million hectares worldwide in a very short period of time following the first major commercial product release in 1996 (James, 2011). Nonetheless, public acceptance of these new agricultural commodities is still an open question. Misperceptions, inaccurate information and/or lack of knowledge, and exaggerated claims by both proponents and opponents all contribute to confusion (Traynor et al., 2007). These public misperceptions may be partially a result of inaccessibility of credible information. Given that the internet can be a first source of information for many who are unfamiliar with a topic, we posed the following questions: Which website links are retrieved from initial internet searches? What kind of information is available from those sites? How much is available? What is the credibility of the content? Understanding the nature of information available on the internet about plant biotechnology, and which sites are most likely to be retrieved, can generate a knowledge base necessary to ensure more effective communication with the public.

A first step for many is a keyword or question-based query using an internet search engine. Assessing the quality of websites obtained from such searches is one approach to answering the above questions. In this study, we used the most popular search engine, Google (Search Engine Watch, 2011), to examine different keywords people use to search about topics related to plant biotechnology and to determine which websites are listed in response to keyword queries. We then evaluated the information found in the 25 top listed websites obtained by querying with the keywords: 'plant biotechnology', 'plant genetic engineering', 'genetically modified organisms', 'GMO', 'LMO' and 'living modified organisms'. We also evaluated other websites that were recommended by these top-listed websites for information on plant biotechnology.

The website quality assessment criteria were adopted with modifications from the principles outlined by Health on the Net (HON) code of conduct (<http://www.hon.ch/>), an internationally accredited set of standards used to evaluate medical and health information on the internet and protect the public from misinformation. The quality parameters, such as transparency and objectivity, are not specific to medical information and are relevant for assessing scientific information on any topic. We asked four guiding research questions: What is the quality of websites available to the public for everyday

life decision-making about plant biotechnology? Do the keywords used to search affect the quality of the website retrieved and content of the information? Does the affiliation of the website affect its quality? Can we identify high quality websites that provide credible information to the public on plant biotechnology?

2 Materials and methods

2.1 Examination of keywords

The Google Adwords Keyword Tool (<https://adwords.google.com/select/KeywordToolExternal>) was used on 5 July 2011 to provide estimates of the volume of the keyword searches related to plant biotechnology. The keywords 'plant biotechnology', 'plant genetic engineering', 'genetically modified organisms', 'GMO', 'living modified organisms' and 'LMO' were entered into the online tool to determine estimates of their average global monthly search frequency, based on the previous 12-month period, and the search frequency of related keywords or phrases suggested by the tool.

2.2 Selection of websites

The Google (<http://www.google.com>) search engine was used on 15 June 2008, 10 December 2009, and 19 July 2011, to generate lists of internet sites. Google was selected because it is the most popular search engine and updates indexing very often by recalculating the page rankings of each website (Search Engine Watch, 2011). Six key words were used to search for websites related to plant biotechnology: 'plant biotechnology', 'plant genetic engineering', 'genetically modified organisms' 'GMO', 'living modified organisms' and 'LMO'. In each case, we selected the first 25 websites listed, with the exception of those that were primarily advertisements, commercial product catalogues, or individual articles with a narrow topic focus. All of the selected websites from the original Google generated list for each term were explored to identify other websites recommended for further reading or linked to by the original group. This provided an additional 18 websites for evaluation.

2.3 Keyword analysis using Google Trends and Google Insights for Search

Google Trends (<http://www.google.com/trends>) is an online information tool that allows users to determine the frequency of Google searches performed with certain words or phrases over time. Entering a search term will give weekly search frequency data (beginning from January 2004, when data collection began, to the present day), and lists that illustrate the countries, cities, and languages most frequently using those terms. The rankings are determined by calculating a ratio of the number of times a given keyword is searched for, compared to the total number of searches done in that region, city or language. The highest frequency is given a value of 1.0, all other values are assigned relative to the top value. The selected keywords were submitted to Google Trends on 10 December 2009.

Google Insights for Search (<http://www.google.com/insights/search/>) allows analysis of search term usage by location including sub-regions and metropolitan areas, and across time ranges. All data are normalised and scaled relative to the highest search value from

the time range specified. The highest value is set to 100, all other search values are returned as percentages of the highest value. This allows comparison between regions of greatly different search volumes and across time, giving the likelihood of a Google user from a region(s) searching for particular term at specific times. All selected keywords were entered into the tool on 18 July 2011.

2.4 *Evaluation of quality of the websites*

The original websites for obtained from the Google search for each category were initially accessed via the URL obtained from the original Google search. Quality analysis of the websites for keywords 'plant biotechnology', 'plant genetic engineering', 'genetically modified organisms' and 'GMO' was performed 01 June 2008 to 31 August 2008; analysis of the websites for 'living modified organisms' and 'LMO' was performed in December 2009. The selected websites were categorised by affiliation (i.e., the person/group or organisation that owns and publishes the website) based on information obtained from the homepage or 'about us' webpage into one of the following groups:

- 1 government/intergovernmental organisations
- 2 university/research centres
- 3 professional groups
- 4 commercial
- 5 non-profit or non-governmental organisations (NGOs)
- 6 blogs/personal
- 7 others
- 8 no indication.

Each website was examined to assess topics covered. The homepage and at least three additional pages (i.e., news stories, subject articles, publications) within each site were read carefully to evaluate quality factors using the criteria described below.

Methods and parameters for evaluation of quality of the internet sites were adapted from the work of Perez-Lopez and Perez-Roncero (2006) who used a procedure based on criteria of Silberg et al. (1997) and the principles outlined by HON code of conduct (<http://www.hon.ch/>) for website evaluation in medical science. Quality of content was assessed using six parameters:

- a frequency of updates [i.e., dates of original posting and updates (referred to as 'currency' in HON)]
- b subject depth (i.e., breath or depth of coverage of particular topics related to plant biotechnology)
- c declaration of authorship of articles [i.e., were the author's name, credentials, affiliation and contact provided? (adapted from 'ownership' in Perez-Lopez and Perez-Roncero)]

- d indication of source of information [i.e., was source of the information cited within the article and/or a list of references or links to the source provided at the end of the article?]
- e credibility of the source of information [i.e., were recognised authorities, official statements from a recognised institution, or publications that have undergone peer review cited? (referred to as ‘type of the source’ in HON)]
- f neutrality [i.e., was verifiable factual information used to support opinions? was exaggerated language used either for or against the technology? (referred to as ‘balance’ in HON and ‘bias’ in McInerney and Bird, 2005)].

Table 1 Evaluation criteria for general quality of the websites

Quality criteria ¹	Score		
	1	2	3
A. Content quality²			
Frequency of updates	< 6 months	6–12 months	>12 months
Subject depth	Extensive coverage	Moderate coverage	Limited coverage
Declaration of authorship ³	Credentials clearly stated	Some indications	No indication
Indication of source of information ⁴	Clearly stated	Some indication	No indication
Credibility of source ⁵	Peer reviewed or credible organisation	Not peer reviewed or credible organisation	Source not indicated
Neutrality of website ⁶	Neutral	Moderately neutral	Biased
B. User friendliness⁷			
Interactivity	Clear invitation to comment	Contact information provided	No details available
Navigability	Links easy to follow	Links difficult to follow	Scattered information

Notes: ¹Overall quality of the website is the sum of the scores for content quality and user friendliness.

²Content quality is the sum of scores for frequency of update, comprehensiveness of the subject matter, declaration of authorship, indication of source, source credibility and neutrality.

³Declaration of authorship of articles refers to whether the author’s name, credentials, affiliation and contact were provided.

⁴Indication of source of information – sources were cited within the article and/or a list of references or links to the source was provided.

⁵Credibility of source refers to whether recognised authorities, official statements from a recognised institution, or publications that have undergone peer review were cited.

⁶Evaluation of neutrality was based on whether verifiable factual information was used to support opinions and whether exaggerated language was used either for or against the technology.

⁷User-friendliness is the sum of scores for interactivity and navigability.

In addition to content quality, user-friendliness of the website was assessed using two parameters adopted from Perez-Lopez and Perez-Roncero (2006): interactivity (i.e., is there invitation to comment on article, ask questions, or contact the authors?) and navigability (i.e., is it is easy to find the information by following the links, does the website have a clear sitemap?).

Each parameter was scored on a scale of 1–3. The basis for each rating score for each category is indicated in Table 1. The total possible score for the six content quality parameters ranged from 6 to 18. A cumulative score was determined for each website as a sum of the quality of content and user friendliness scores with a total possible score between 12 and 24. Evaluation was carried out independently for each websites by two of the authors (BZ, SS). In cases where the difference in cumulative score was greater than 2, a third assessor was involved in the evaluation. If there was still a discrepancy, a team evaluation was done to come to a consensus, although this happened less than five times. Relationships among keyword choice, website affiliation and content quality were analysed using SAS (SAS for Windows 9.2, SAS Institute Inc. Cary, NC) analysis of variance (ANOVA) test with means separated using Duncan's Multiple Range Test at $p \leq 0.05$. Generalised linear models for content quality components as predictors of total content quality were produced using SAS.

3 Results

3.1 Selected keyword and related terms search frequency

The Adwords Keywords Tool was used to estimate global search frequency for the selected keywords, as well as related terms identified by the Google tool. 'GMO' had the highest average monthly global search frequency with over 820,000 Google searches, greatly exceeding use of the other terms, 'genetically modified organisms' with less than 50,000 searches, 'plant biotechnology' with 27,000 and 'plant genetic engineering' with approximately 8,000 (Table 2). 'Living modified organisms' was the least searched of the selected keywords with less than 400 searches per month. Results for 'LMO' were omitted as all keywords returned by the online tool were unconnected to plant biotechnology. Related keywords suggested by the tool differed considerably depending on which of the selected keywords was entered. 'Plant biotechnology' returned mostly industry related terms, while 'GMO' and 'genetically modified organisms' related keywords were more frequently linked to genetically modified foods. Although the selected keywords did not always have the highest search frequency, a high degree of overlap was found between these keywords and the related search terms suggested by the tool. These results support the keywords selected for the Google searches that yielded the assessed websites.

Table 2 Average global search frequency using Google for selected search terms and related keywords

<i>Plant biotechnology</i>		<i>GMO</i>	
<i>Keyword</i>	<i>Average global monthly searches</i>	<i>Keyword</i>	<i>Average global monthly searches</i>
<u>biotechnology</u>	1,830,000	'gmo'	823,000
<u>biotech</u>	1,830,000	what is <u>gmo</u>	823,000
what is <u>biotechnology</u>	1,830,000	genetically modified	823,000
biomedical	1,220,000	genetically engineered	550,000
biochemistry	1,000,000	monsanto	450,000
<u>bio tech</u>	673,000	<u>gmo</u> genetically modified	450,000
<u>bio technology</u>	550,000	<u>gm</u> os	301,000
bioinformatics	368,000	genetically modified food	246,000
bioscience	368,000	genetically modified foods	246,000
tissue culture	246,000	transgenic	201,000
<u>biotechnologie</u>	246,000	genetically engineered foods	201,000
<u>biotech</u> companies	135,000	genetically engineered food	201,000
<u>biotechnology</u> companies	110,000	<u>gmo</u> foods	110,000
<u>biotechnology</u> company	110,000	genetically altered food	110,000
<u>biotech</u> jobs	90,500	<u>gmo</u> crops	90,500
<u>biotechnology</u> jobs	90,500	<u>gmo</u> food	74,000
<u>plant</u> tissue	90,500	<u>gmo</u> in food	74,000
jobs in <u>biotechnology</u>	90,500	genetically modified organisms	49,500
<u>biotechnology</u> journal	60,500	genetic modification	40,500
journal of <u>biotechnology</u>	60,500	<u>gmo</u> products	40,500
<u>plant</u> tissue culture	49,500	genetically modified organism	33,100
<u>plant</u> breeding	49,500	transgenic animals	33,100
<u>biotechnology</u> careers	49,500	non- <u>gmo</u>	22,200
<u>biotechnology</u> industry	49,500	<u>gmo</u> plants	22,200
<u>plant</u> technology	49,500	no <u>gmo</u>	18,100
help <u>biotech</u>	40,500	jeremy grantham	14,800
<u>biotechnology</u> career	40,500	transgenic organisms	14,800
career in <u>biotechnology</u>	40,500	genetically modified seeds	9,900
'plant biotechnology'	27,100	<u>gmo</u> benefits	8,100
what is <u>plant</u> <u>biotechnology</u>	27,100	<u>gmo</u> free	8,100

Notes: Average global search frequency is the approximate 12-month average number of search queries submitted, in all countries and languages, to the Google search engine for each keyword.

Keywords were generated using the Google Adwords Keywords Tool. The selected search terms (plant biotechnology, GMO, etc...) were submitted and the related keywords returned were listed beneath the corresponding search term. The exact match is shown in 'bold'. Partial Matches are underlined.

Table 2 Average global search frequency using Google for selected search terms and related keywords (continued)

<i>Genetically modified organisms</i>		<i>Plant genetic engineering</i>	
<i>Keyword</i>	<i>Average global monthly searches</i>	<i>Keyword</i>	<i>Average global monthly searches</i>
<u>genetically</u>	1,000,000	what is genetic engineering	368,000
<u>genetically modified</u>	823,000	<u>plant</u> breeding	49,500
what is <u>genetically modified</u>	823,000	<u>genetic</u> modification	40,500
what are gmo	823,000	<u>genetically engineered plants</u>	33,100
<u>genetically</u> engineered	550,000	<u>plants</u> breeding	18,100
gmo <u>genetically modified</u>	450,000	<u>genetic engineering</u> animals	14,800
gmos	301,000	<u>genetic engineering</u> in animals	14,800
<u>genetically modified</u> food	246,000	<u>genetic engineering</u> of animals	14,800
<u>genetically modified</u> foods	246,000	<u>plants genetic engineering</u>	12,100
what is <u>genetically modified</u> foods	246,000	<u>genetic engineering</u> in <u>plants</u>	12,100
what are <u>genetically modified</u> food	246,000	<u>genetic engineering</u> plants	12,100
what is <u>genetically modified</u> food	246,000	<u>genetic engineering</u> of <u>plants</u>	12,100
what are <u>genetically modified</u> foods	246,000	<u>genetic engineering</u> on <u>plants</u>	12,100
<u>genetically modified</u> crops	201,000	<u>genetic engineering</u> for <u>plants</u>	12,100
<u>genetically</u> altered	201,000	<u>genetically engineered</u> plant	9,900
<u>genetically</u> engineered food	201,000	'plant genetic engineering'	8,100
<u>genetically modified</u> products	135,000	<u>genetic plant engineering</u>	8,100
gmo foods	110,000	<u>genetic engineering</u> plant	8,100
<u>genetic modified</u>	74,000	<u>genetic engineering</u> in <u>plant</u>	8,100
what is gmo food	74,000	<u>genetic engineering</u> of <u>plant</u>	8,100
'genetically modified organisms'	49,500	<u>genetic engineered</u> plants	6,600

Notes: Average global search frequency is the approximate 12-month average number of search queries submitted, in all countries and languages, to the Google search engine for each keyword.

Keywords were generated using the Google Adwords Keywords Tool. The selected search terms (plant biotechnology, GMO, etc...) were submitted and the related keywords returned were listed beneath the corresponding search term. The exact match is shown in 'bold'. Partial Matches are underlined.

Table 2 Average global search frequency using Google for selected search terms and related keywords (continued)

<i>Genetically modified organisms</i>		<i>Plant genetic engineering</i>	
<i>Keyword</i>	<i>Average global monthly searches</i>	<i>Keyword</i>	<i>Average global monthly searches</i>
what are <u>genetically modified organisms</u>	49,500	<u>genetically engineering plants</u>	5,400
what is <u>genetically modified organisms</u>	49,500	ti plasmid	4,400
<u>genetically modified plants</u>	49,500	<u>genetic engineering</u> research	2,900
<u>genetic</u> modification	40,500	<u>plant genetic</u> modification	1,900
<u>genetically modified organism</u>	33,100	<u>genetic</u> modification animals	1,300
<u>genetically modified organisms</u> gmo	33,100	<u>genetic engineering</u> of <u>plants</u> and animals	880
what is <u>genetically modified organism</u>	33,100	benefits of <u>genetic engineering</u> in <u>plants</u>	720
<u>genetically</u> engineered <u>organisms</u>	33,100	<u>genetically engineered plants</u> and animals	590
<u>organism</u> <u>genetically modified</u>	33,100	<u>genetically engineered plants</u> list	480

Notes: Average global search frequency is the approximate 12-month average number of search queries submitted, in all countries and languages, to the Google search engine for each keyword.

Keywords were generated using the Google Adwords Keywords Tool. The selected search terms (plant biotechnology, GMO, etc...) were submitted and the related keywords returned were listed beneath the corresponding search term. The exact match is shown in 'bold'. Partial Matches are underlined.

3.2 Comparison of websites identified by different search terms

The first 25 websites retrieved from the Google search engine for each of six different keywords ('plant biotechnology', 'plant genetic engineering', 'genetically modified organisms' 'GMO', 'living modified organisms' and 'LMO') were compared to each other for shared listings (Table 3). We recognise that in many cases, readers will not look beyond the websites that are listed on the first page recovered by the search (typically approximately ten sites), however, we chose to include a larger group of websites (25 per keyword) to have a more complete assessment of the kinds of sites obtained, and to allow for increased chance for overlap among sites obtained when searching with different keywords. There was little commonality among the sites obtained using the different keywords. In fact, there was no website retrieved by more than four keywords and only one website, Wikipedia, was common to four keywords ('genetically modified organisms', 'GMO', 'living modified organisms' and 'LMO').

The Monsanto website was common to three keywords ('plant biotechnology', 'genetically modified organism' and 'GMO'). Only five websites Wikipedia, Monsanto, Human Genome Project Info, Food and Agriculture Organization – United Nations (FAO), and EUROPA appeared for more than one keyword.

Table 3 Overlap in websites obtained when searching with each of the different keywords

<i>A. Keywords – 2008</i>	<i>Number of sites</i>	<i>PB</i>	<i>PGE</i>	<i>GMO full</i>	<i>GMO</i>		
Plant biotechnology (PB)	6	-	0	1	1		
Plant genetic engineering (PGE)	8		-	0	0		
Genetically modified organisms (GMO full)	13			-	3		
GMO	17				-		
<i>B. Keywords – 2009</i>	<i>Number of sites</i>	<i>PB</i>	<i>PGE</i>	<i>GMO full</i>	<i>GMO</i>	<i>LMO full</i>	<i>LMO</i>
Plant biotechnology (PB)	8	-	1	1	1	0	0
Plant genetic engineering (PGE)	11		-	0	0	0	0
Genetically modified organisms (GMO full)	21			-	6	1	2
GMO	17				-	1	1
Living modified organisms (LMO full)	14					-	1
LMO	1						-

Despite the fact that 'GMO' is an abbreviation of 'genetically modified organisms', there were only three overlapping websites between those obtained with the keyword 'GMO' versus 'genetically modified organisms' in 2008 and six in 2009 (Table 3). Living modified organisms and its abbreviation LMO is the terminology used in the Cartagena Protocol on Biosafety and in many national legal documents regarding genetically engineered crops (Low and Frederick, 2011). However, of the first 25 websites generated using the keyword 'LMO', only one website (Wikipedia) was related to plant biotechnology. For 'living modified organisms' 14 relevant websites were retrieved. These observations underline the importance of even minor differences in keyword choice.

Although exact rankings of websites varied over time, comparison among rankings obtained for 40 websites from searches on 15 June 2008 with searches on 10 December 2009 and 19 July 2011, showed positive associations (correlation coefficients 0.384–0.652; $p < 0.001$ –0.014), indicating similar relative rankings. However, only 27 of the 40 sites in the top 25 from 2008 reappeared in the top 25 for their respective keywords in 2009 (Table 4), reflecting fluidity in the ranking.

Table 4 Keyword and top Google ranked websites with their affiliation

Keyword and website	Web address	Affiliation ¹	Google rank		
			2008	2009	2011
A					
Plant biotechnology					
1 Virginia Polytechnic Institution	http://www.ext.vt.edu/pubs/biotech/443-002/443-002.html	Univ/res	1	- ²	-
2 Monsanto	http://www.monsanto.com/biotech-gmo/asp/default.asp	Commercial	2	4	6
3 Biotech Basics	http://www.biotechknowledge.com	Commercial	7	3	-
4 Council for Biotechnology Information	http://www.whibiotech.com/index.asp?id=3624	Non-prof/NGO	10	-	-
5 Biotech Info.net	http://www.biotech-info.net/gordon_conway.html	Non-prof/NGO	17	19	-
6 USDA, CSREES	http://www.esrees.usda.gov/biotechnology.cfm	Gov/internat	25	9	1
B					
Plant genetic engineering					
1 Arizona State University	http://photoscience.la.asu.edu/Photosyn/courses/BIO_343/lecture/geneng.html	Univ/res	1	1	-
2 Access Excellence	http://www.accessexcellence.org/AB/BA/Transforming_Plants.html	Univ/res	2	3	7
3 Church of Scotland	http://www.srtp.org.uk/geneng2.htm	Non-prof/NGO	5	5	-
4 University of Nebraska, AgBiosafety	http://agbiosafety.unl.edu/education/summary.htm	Univ/res	6	2	1
5 Yale-New Haven Teachers Institute	http://www.yale.edu/ynhti/curriculum/units/2000/7/00.07.02.x.html	Univ/res	7	-	25
6 US Food and Drug Authority	http://www.fda.gov/fdac/features/2003/603_food.html	Gov/internat	10	12 ³	-
7 American Society of Plant Biologists	http://www.aspb.org/publicaffairs/aspbgstatement.cfm	Prof. group	20	11	23
8 Organic Consumers Association	http://www.purefood.org/text.html	Non-prof/NGO	24	-	-

Notes: Website lists include the first 25 sites retrieved by Google search for the different keywords accessed on 15 June 2008, 10 December 2009 or 19 July 2011. Internet sites of advertisements, commercial product catalogues, or individual articles with a narrow topic focus were not included.

¹Affiliation is the person/group or organisation that owns and publishes the website.

Abbreviations: Univ/res – university or research organisation,

Gov/internat – governmental or international agency or organisation,

Prof. group – professional group.

²Websites that did not appear in the top 25 Google ranked sites in 2009 and/or 2011 are marked as '-'.³

³Website Google ranking when using a different keyword.

⁴Data not collected only in 2008.

Table 4 Keyword and top Google ranked websites with their affiliation (continued)

Keyword and website	Web address	Affiliation ¹	Google rank		
			2008	2009	2011
C Genetically modified organisms					
1 Wikipedia	http://en.wikipedia.org/wiki/Genetically_modified_organism	Other	1	1	1
2 Human Genome Project Info	http://www.ornl.gov/hgmis/elsi/gmfood.shtml	Gov/internat	2	2	2
3 New Scientist	http://www.newscientist.com/channel/life/gm-food	Prof. group	3	11	17
4 Health and Safety Executive	http://www.hse.gov.uk/biosafety/gmo/	Gov/internat	9	-	-
5 European Food Safety Association	http://www.efsa.eu.int/EFSA/ScientificPanels/efsa_locale-1178620753812_GMO.htm	Gov/internat	14	23	19
6 GM Compass	http://www.gmo-compass.org/	Non-prof/NGO	15	8	12
7 Food and Agriculture Organization (FAO)	ftp://ftp.fao.org/docrep/fao/006/y4955e/Y4955E00.pdf	Gov/internat	16	-	-
8 Greenpeace	http://www.greenpeace.org/international/campaigns/genetic-engineering	Non-prof/NGO	17	9	-
9 Europa-Europe	http://reports.eea.europa.eu/environmental_issue_report_2002_28	Gov/internat	18	-	-
10 European Regulations	http://www.opsi.gov.uk/si/si2002/20022443.htm	Gov/internat	20	-	-
11 South African Act	http://www.info.gov.za/acts/1997/act15.htm	Gov/internat	23	-	-
12 Australian Government	http://www.environment.gov.au/soe/2006/publications/emerging/gmo/index.html	Gov/intergov	24	-	-

Notes: Website lists include the first 25 sites retrieved by Google search for the different keywords accessed on 15 June 2008, 10 December 2009 or 19 July 2011. Internet sites of advertisements, commercial product catalogues, or individual articles with a narrow topic focus were not included.

¹Affiliation is the person/group or organisation that owns and publishes the website.

Abbreviations: Univ/res – university or research organisation,

Gov/internat – government or international agency or organisation,

Prof. group – professional group.

²Websites that did not appear in the top 25 Google ranked sites in 2009 and/or 2011 are marked as ‘-’.

³Website Google ranking when using a different keyword.

⁴Data not collected only in 2008.

Table 4 Keyword and top Google ranked websites with their affiliation (continued)

Keyword and website	Web address	Affiliation ¹	Google rank		
			2008	2009	2011
D					
GMO					
1 Wikipedia	http://en.wikipedia.org/wiki/Genetically_modified_organism	Other	2	2	3
2 Say No to GMO	http://www.saynotogmos.org/	Blog/personal	3	4	6
3 Human Genome Project Info	http://www.ornl.gov/hgmis/elis/gmfood.shtml	Gov/internat	6	5	8
4 GMO Africa	http://www.gmoafrica.org/	Blogs/personal	9	12	17
5 Monsanto	http://www.monsanto.com/biotech-gmo/asp/default.asp	Commercial	12	17	-
6 The Organic and Non-GMO Report	http://www.non-gmoreport.com/	Commercial	14	21	-
7 AgBioWorld, GMO Food for Thought	http://www.gmofoodforthought.com/	Non-prof/NGO	15	19	-
8 GE Free Vermont Campaign	http://www.gefreevt.org/	Non-prof/NGO	16	-	-
9 Non-GMO project	http://www.nongmoproject.org/	Non-prof/NGO	17	16	12
10 GMO ERA	http://www.gmoera.umn.edu/	Univ/res	18	24	30
11 GMO Pundit Web blog	http://gmopundit.blogspot.com/	Blogs/personal	20	-	-
12 Cambridge Information Group	http://www.csa.com/discoveryguides/gmfood/overview.php	Other	21	6	7
13 The Campaign	http://www.thecampaign.org/	Non-prof/NGO	25	25	-

Notes: Website lists include the first 25 sites retrieved by Google search for the different keywords accessed on 15 June 2008, 10 December 2009 or 19 July 2011. Internet sites of advertisements, commercial product catalogues, or individual articles with a narrow topic focus were not included.

¹Affiliation is the person/group or organisation that owns and publishes the website.

Abbreviations: Univ/res – university or research organisation,

Gov/internat – government or international agency or organisation,

Prof. group – professional group.

²Websites that did not appear in the top 25 Google ranked sites in 2009 and/or 2011 are marked as ‘-’.

³Website Google ranking when using a different keyword.

⁴Data not collected only in 2008.

Table 4 Keyword and top Google ranked websites with their affiliation (continued)

Keyword and website	Web address	Affiliation ¹	Google rank		
			2008	2009	2011
E Living modified organisms					
1 Convention on Biological Diversity	http://www.cbd.int/biosafety/further/	Gov/internat	nd ⁴	1	1
2 Wikipedia	http://en.wikipedia.org/wiki/LMO_(biology)	Other	nd	2	3
3 Food and Agriculture Organization (FAO)	http://www.fao.org/newsroom/en/news/2004/43684/index	Gov/internat	nd	3	5
4 European Commission Research, Biosociety	http://ec.europa.eu/research/biosociety/library/glossarylist_en.cfm?Init=L	Gov/internat	nd	4	8
5 Biosafety Clearing House	http://bch.cbd.int/database/lmo-registry/	Gov/internat	nd	7	2
6 Research and Information Systems for Developing Countries	http://www.ris.org.in/vol7no3_article4.pdf	Univ/res	nd	8	-
7 Federal Agency for Nature Conservation, Berlin	http://www.bfn.de/fileadmin/MDB/documents/presse/12-14_05_08_Gentechnik_Biologische_Sicherheit_GVO-Monitoring.pdf	Gov/internat	nd	10	13
8 UN Chronicle	http://www.un.org/wcm/content/site/chronicle/cache/bypass/lang/en/home/archive/issues2008/pid/5108?ctnscroll_articleContainerList=1_0&ctnlstpagination_articleContainerList=true	Gov/internat	nd	14	10

Notes: Website lists include the first 25 sites retrieved by Google search for the different keywords accessed on 15 June 2008, 10 December 2009 or 19 July 2011. Internet sites of advertisements, commercial product catalogues, or individual articles with a narrow topic focus were not included.

¹Affiliation is the person/group or organisation that owns and publishes the website.

Abbreviations: Univ/res – university or research organisation,

Gov/internat – government or international agency or organisation,

Prof. group – professional group.

²Websites that did not appear in the top 25 Google ranked sites in 2009 and/or 2011 are marked as '-'.
³Website Google ranking when using a different keyword.

⁴Data not collected only in 2008.

Table 4 Keyword and top Google ranked websites with their affiliation (continued)

Keyword and website	Web address	Affiliation ¹	Google rank	
			2008	2009 - 2011
E Living modified organisms				
9 Action Bioscience	http://www.actionbioscience.org/genomic/crg.html	Non-prof/ NGO	nd	18
10 World Health Organization (WHO)	http://www.who.int/foodsafety/publications/biotech/20questions/en/	Gov/internat	nd	19
11 Natural Living	http://www.thenaturalguide.com/synthetic-food-GMO.htm	Blogs/personal	nd	21
12 Ministry of Environment, Korea	http://eng.me.go.kr/content.do?method=moveContent&menuCodepol_nat_pol_wil_bio_lmos			
13 Crop Life International	http://www.croplife.org/	Commercial	nd	23
14 Buzzle.com	http://www.buzzle.com/articles/genetically-modifiedorganisms-pros-and-cons.html	Blogs/personal	nd	25
F LMO				
1 Wikipedia	http://en.wikipedia.org/wiki/LMO_(biology)	Other	nd ⁴	2
4				

Notes: Website lists include the first 25 sites retrieved by Google search for the different keywords accessed on 15 June 2008, 10 December 2009 or 19 July 2011. Internet sites of advertisements, commercial product catalogues, or individual articles with a narrow topic focus were not included.

¹Affiliation is the person/group or organisation that owns and publishes the website.

Abbreviations: Univ/res – university or research organisation,

Gov/internat – government or international agency or organisation,

Prof. group – professional group.

²Websites that did not appear in the top 25 Google ranked sites in 2009 and/or 2011 are marked as ‘-’.

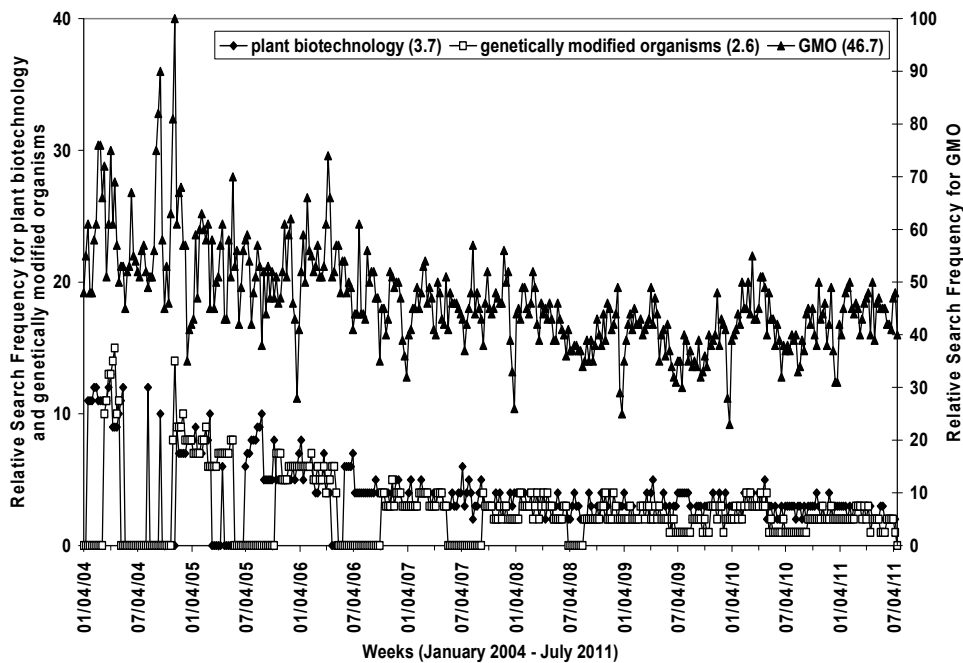
³Website Google ranking when using a different keyword.

⁴Data not collected only in 2008.

3.3 Temporal and geographic trends for use of the different keywords

The different keywords were submitted to Google Insights for Search as a measure of search volume and temporal trends for the different topics. Google Insights for Search gives the relative search frequency by scaling them as percentages of the highest search frequency in the time range, which in this case was for ‘GMO’ on 11 November 2004. This scale caused relative search frequencies for ‘plant genetic engineering’ and ‘living modified organisms’ to be set to zero, and thus omitted from the figure. Of the remaining three keywords, ‘GMO’ was by far the most frequently searched, with an approximately 14-fold greater average relative search frequency from 2004 to 2011 (46.7) than for ‘plant biotechnology’ (3.7) or ‘genetically modified organisms’ (2.6) (Figure 1). For the terms ‘plant biotechnology’ and ‘genetically modified organisms’ there was insufficient Google search traffic for the keyword to be consistently graphed from 2004-2006; use after 2007 was fairly constant, but low.

Figure 1 The relative search frequency for the three keywords: ‘GMO’, ‘genetically modified organisms’ and ‘plant biotechnology,’ by users of the Google search engine from 2004 to 2011 from data generated using Google Insights for Search on 18 July 2011



Notes: Keywords ‘plant genetic engineering’ and ‘living modified organisms’ are not used frequently enough to yield non-zero relative search frequencies. Although keyword ‘LMO’ yielded results in Google Insights for Search, it was not included because only one out of 25 websites was related to plant biotechnology. The search frequency data are normalised based on the global Google search traffic at a given time point and scaled as percentages of the highest search frequency in the time range (‘GMO’ on 11 November 2004). Mean relative search frequencies are given in parentheses after each term.

The three keywords with sufficient search volume for analysis ('plant biotechnology,' 'genetically modified organisms' and 'GMO') also were examined by Google Trends for geographic trends in their usage (Table 5). Different countries appeared to use different keywords with little overlap among the countries preferentially using the different keywords. For 'plant biotechnology,' Ethiopia, India and Pakistan were the top three countries performing searches; for 'genetically modified organisms' it was the Philippines, South Africa and New Zealand, while for 'GMO' it was Thailand, Chile, and Japan. The only country that was listed in the top ten for all the three keywords was the Philippines. Only India, South Korea and South Africa were listed for two of the search terms. With the exception of the UK, countries from South America and Europe only occurred in the list for 'GMO'. The term 'genetically modified organisms' was primarily accessed by English speaking countries (South Africa, New Zealand, Australia, Canada, USA and UK).

Table 5 Top ten countries using various keywords as ranked by Google Trends

<i>Term (relative frequency of use relative to the other terms)</i>						
<i>Rank</i>	<i>Plant biotechnology (1.0)</i>		<i>Genetically modified organism (0.8)</i>		<i>GMO (21.8)</i>	
	<i>Country</i>	<i>Relative frequency within term</i>	<i>Country</i>	<i>Relative frequency within term</i>	<i>Country</i>	<i>Relative frequency within term</i>
1	Ethiopia	1.00	Philippines	1.00	Thailand	1.00
2	India	0.28	South Africa	0.27	Chile	0.81
3	Pakistan	0.17	New Zealand	0.18	Japan	0.64
4	South Korea	0.10	Australia	0.16	South Korea	0.56
5	Iran	0.09	India	0.14	Philippines	0.39
6	Malaysia	0.07	Canada	0.14	Peru	0.38
7	South Africa	0.07	Singapore	0.11	Colombia	0.24
8	Philippines	0.05	USA	0.09	Sweden	0.20
9	Egypt	0.03	UK	0.04	Poland	0.17
10	Taiwan	0.02	Turkey	0.02	Denmark	0.15

Notes: The locations are ranked by the ratio of search term usage compared to total Google searches. The numerical values given after the location allow for comparison between terms, with the highest ranked always given a value of 1.0. Thus comparisons can be made only within a top ten ranking, not across search terms. Keywords 'plant genetic engineering' and 'living modified organisms' are not used frequently enough for the search engine to yield results in Google Trends. Although keyword 'LMOs' yielded results in Google Trends, it was not included because only one out of 25 websites was related to plant biotechnology.

3.4 Evaluation of quality of the websites

The first 25 websites obtained from the Google search engine for the six different keywords were compiled into a list of 150 sites. Websites whose content was unrelated to plant biotechnology, were eliminated from the quality analysis; websites that did not provide general information about the topic, such as those representing product advertisements, commercial product catalogues and scientific peer reviewed journal articles with a narrow topic focus also were removed. For all of the search terms except 'plant genetic engineering', the winnowing process did not result in removal of the first two websites retrieved by the original Google search (i.e., presumably did not remove those websites most likely to be accessed). In 2008, a total of 40 websites (Table 4) was retrieved from the keyword searches including 13 websites for 'genetically modified organism' and for 'GMO'; eight for 'plant genetic engineering'; and six for 'plant biotechnology'.

The websites were evaluated for quality of the content related to plant biotechnology and user-friendliness as defined in the methods section (Table 6). The mean total content quality score for all websites was 13.8 of a possible 18; the mean overall quality score (content plus user-friendliness) was 19.2 of a possible 24. Generalised linear model analysis of factors contributing to total content quality showed that credibility of the source of information had the highest contribution, followed by neutrality, indication of source, and declaration of the author, all of which had a highly significant contribution ($p < 0.001$) to the content quality (Table 6). Comprehensiveness of the subject matter also had a significant contribution ($p < 0.05$) with the content quality, while frequency of update did not.

Table 6 Total content quality and overall quality for the 40 websites rated in 2008 (A) and regression analysis of contributions of individual quality components to total content quality rating (B)

<i>A. Website quality scores</i>		<i>Mean ± S.D.</i>	<i>Range</i>	
Total content quality ¹		13.79 ± 2.37	8 – 17.5	
Overall quality (content quality + user friendliness) ²		19.19 ± 2.55	13 – 23.5	
<i>B. Quality parameter</i>	<i>Mean ± S.D.</i>	<i>R²</i>	<i>F-value</i>	<i>p-value</i>
Frequency of update	2.43 + 0.71	0.030	0.27	0.896
Subject depth	2.29 + 0.50	0.360	4.92	0.003
Declaration of author	2.11 + 0.69	0.496	8.60	<0.001
Indication of source of information	2.40 + 0.71	0.546	10.52	<0.001
Credibility of source	2.34 + 0.65	0.713	21.74	<0.001
Neutrality	2.23 + 0.84	0.664	23.71	<0.001

Notes: ¹Total content quality is the sum of scores for frequency of update, subject depth, declaration of author, indication of source of information, credibility of source and neutrality for a maximum possible score of 18.

²Overall quality is the sum of total content quality plus + friendliness, with a maximum total score of 24. User friendliness is the sum of interactivity and navigability.

Comparison of the websites by type of affiliation (Table 7) showed that government and university/research institute-sponsored websites had higher mean content quality than non-profit/non-governmental organisations or commercially affiliated sites. Websites associated with government and university/research institute-sponsored websites were more frequently retrieved when searching with the lesser used terms of ‘genetically modified organism’ and ‘living modified organism’ (i.e., 8/13 and 9/14 listings for these terms were for government and intergovernmental agencies Table 4C,F). ‘Plant genetic engineering’ was most commonly used by universities/research institutes (4/8). The abbreviation ‘GMO’ was preferred by non-profit organisations/NGOs or blogs (7/13). Anti-GMO organisations were most frequently retrieved by the GMO keyword (5/13; Table 4D). No significant difference was observed in the content quality for the different keywords (Table 7). There was also no significant correlation observed between the content quality and the Google ranking ($R = 0.000$; $p = 0.993$), i.e., Google ranking was not a predictor of quality as assessed by these criteria.

Table 7 Relationship between affiliation of the selected websites, and their Google ranking, keywords used and total content quality from data collected in 2008

Affiliation	Number of websites	Mean Google ranking	Mean total content quality for each keyword (number of websites)				Mean total content quality score \pm S.D.
			Plant biotechnology	Plant genetic engineering	Genetically modified organisms	GMO	
1 Government	11	15	17.0(1)	17.5(1)	15.4(8)	15.5(1)	15.7 + 1.97a ¹
2 University/ research inst.	6	6	15.0(1)	14.4(4)	-	16.0(1)	14.8 + 1.29a
3 Commercial	4	8	12.5(2)	-	14.0(1)	12.0(2)	12.6 + 1.95b
4 Non-profit/ NGO	10	18	14.8(2)	11.0(1)	11.8(2)	12.5(5)	12.7 + 2.27b
Mean total content quality score			14.4a	14.3a	14.6a	13.1a	14.1 + 2.36

Notes: Only those affiliation categories that appeared at least five times among the first 25 websites listed for each of the various keywords were included in the analysis. Blogs and ‘others’ affiliations had only three websites each while professional groups only had two websites.

¹Average scores denoted by same letter are not significantly different, based on Duncan’s multiple range test ($p \leq 0.05$).

3.5 Determination of quality of recommended website links

Many of the 40 websites selected in 2008 linked readers to obtain further information from additional websites. Those links led to 31 websites, of which 18 were not among the original Google search-derived list. These additional 18 recommended websites had a higher mean overall quality score and narrower range of scores (mean = 21.3, range 19-24) than the set originally obtained based on Google ranking (mean = 19.2, range = 13-25) (t-test, $p = 0.0003$). Based on the websites originally retrieved by Google

search and 18 additional websites recommended by the first group, the 20 websites with the highest content quality are listed in Table 8. All had content quality ratings of 16–18 and user friendliness ratings of 5–6. Of this group, 11 have a government/inter-governmental organisation affiliation, five are from a university/research institution, three are from non-profit/non-governmental organisations, and one had commercial affiliation. Only two were within the first ten retrieved by Google searches, i.e., would typically ‘show-up’ on the first page of search results. Only 8 of the 20 highest quality websites were either originally identified by the Google search or had the same publisher. The other 12 websites, which were recommended by links from the original group, were predominantly affiliated with government/international agencies and universities or research centres (9 of the 12 websites).

4 Discussion

The Google search engine was selected to identify the websites likely to be retrieved when querying about topics related to plant biotechnology. While the results of this study reflect a few points in time, and specific websites retrieved can change over time, they provide insight into websites likely to be encountered, factors influencing which websites may be encountered, and quality of websites and information. The first criteria observed to influence information obtained was keyword. Depending on the search term chosen, virtually non-overlapping websites were obtained. Differences occurred not only in the specific websites retrieved with the different keywords, but also the affiliations and general categories of the websites. For example, searches that included the term ‘biotech’ or ‘biotechnology’ tended to retrieve primarily industry and scientific websites, while searches including the term ‘genetically modified’ tended to yield websites more directed to the lay audience. Even though ‘GMO’ is an abbreviation of ‘genetically modified organisms’, these search terms also yielded different top 25 Google ranked websites, with only three overlapping websites. Most government-owned websites tended to write out the full term ‘genetically modified organisms’ or ‘living modified organisms’, at least some portion of the time, while the abbreviation ‘GMO’ was commonly used by non-profit or non-governmental organisations including anti-biotechnology organisations, and blogs. This supports prior studies related to health science and nanotechnology indicating that the selection of search terms may critically influence which websites are retrieved (e.g., Anderson et al., 2010; Eachus, 1999; Eysenbach et al., 2002; Ladwig et al., 2010).

The search term chosen also varied with respect to frequency of use, and among different countries. The Google Insights for Search tool provided further evidence into the relevance of the different keywords (‘plant biotechnology,’ ‘genetically modified organisms’ and ‘GMO’) as illustrated by the frequency of search traffic for the different terms. Since 2004, the term ‘GMO’ was queried globally approximately 14 times more frequently than ‘genetically modified organisms.’ This disparity between the use of a phrase and its abbreviation was highlighted by the Google Trends tool and is important for website developers as there was only a single country, the Philippines, which appeared on the top ten lists for both search terms.

Table 8 Top 20 quality websites identified from the Google search and recommended links with their affiliation, Google ranking and search term or the websites that recommended the site

<i>Website</i>	<i>Affiliation</i>	<i>Google ranking</i>	<i>Keyword for Google ranking or websites that recommended the site</i>
AgBios http://www.agbios.com/	Commercial	-	GMO Africa Monsanto Virginia Polytechnic Institution
AgBioWorld, GMO Food for Thought http://www.gmofoodforthought.com/	Non-profit organisation/NGO	15	GMO
BioPortal, Canada http://www.biportal.gc.ca/	Government/ international organisation	-	Biosafety Clearing House, Virginia Polytechnic Institution
Biosafety Clearing House (BCH) http://beh.biodiv.org	Government/ international organisation	-	GM Compass European Regulations South African Act Virginia Polytechnic Institution
Biotech in Food and Agriculture http://www.fao.org/biotech/	Government/ international organisation	16	<i>Genetically modified organisms</i>
Biotechnology, Australia, http://www.biotechnology.gov.au/index.cfm	Government/ international organisation	24	<i>Genetically modified organisms</i>
Codex Alimentarius Commission http://www.codexalimentarius.net/	Government/ international organisation	-	GM Compass AgBioWorld, GMO Food for Thought Human Genome Project Info
EUROPA – Food Safety-Biotechnology http://ec.europa.eu/food/food/biotechnology/	Government/ international organisation	18	<i>Genetically modified organisms</i>
European Food Safety Association http://www.efsa.europa.eu/EFSA/ScientificPanels/efsa_locale-1178620753812_GMO.htm	Government/ international organisation	14	<i>Genetically modified organisms</i>
GMO Environmental Risk Assessment http://www.gmoera.umn.edu/	University/research centre	18	GMO
ICGEB-Biosafety Unit http://www.icgeb.org/~bsafesrv/	University/research centre	-	Virginia Polytechnic Institution
IFPRI http://www.ifpri.org/pbs/pbs.asp	University/research centre	-	GMO ERA Virginia Polytechnic Institution

Note: Data was accessed on August 16, 2008.

Table 8 Top 20 quality websites identified from the Google search and recommended links with their affiliation, Google ranking and search term or the websites that recommended the site (continued)

Website	Affiliation	Google ranking	Keyword for Google ranking or websites that recommended the site
ISAAA http://www.isaaa.org/	Non-profit organisation/NGO	-	Biotech Info.net GMO Africa GMO ERA GM Compass Monsanto
OECD http://www.oecd.org/	Government/international organisation	-	Virginia Polytechnic Institution Australian Government GM Compass European Regulations Virginia Polytechnic Institution
SciDevNet http://www.scidev.net/en/agriculture-and-environment/agri-biotech/	Non-profit organisation/NGO	-	GMO Africa
United Nations Environment Programme (UNEP) http://www.unep.org/biosafety/	Government/international organisation	-	GMO Africa South African Act Virginia Polytechnic Institution
University of California, Davis http://sbc.ucdavis.edu/Outreach and http://ppge.ucdavis.edu/Transformation/transform1.cfm	University/research centre	-	Arizona State University Lecture University of Nebraska AgBiosafety
US Food and Drug Authority http://www.fda.gov/ftdc/features/2003/603_food.html	Government/international organisation	10	<i>Plant genetic engineering</i>
WHO Food Biotech http://www.who.int/foodsafety/biotech/en/	Government/International organisation	-	Human Genome Project Info
Virginia Polytechnic Institution http://www.isb.vt.edu/and http://www.ext.vt.edu/pubs/biotech/443-002/443-002.html	University/research centre	1	<i>Plant biotechnology</i>

Note: Data was accessed on August 16, 2008.

The top ten countries for both 'GMO' and 'genetically modified organisms' were equally split between developed and developing nations, however this is not the case for the term 'plant biotechnology' where the ten top searching countries were predominantly developing nations. Thus, not only do different websites appear as a result of using different keywords, but also the viewers of those websites differ in location and level of economic development. This difference is critical to institutions and organisations developing websites depending on an intended audience. For example, a website intending to provide information to regulatory bodies in the developing world may consider using the term 'plant biotechnology'.

A number of user friendliness and content quality criteria were used to evaluate the websites. Interactivity took into account whether provision was made to allow the user to make inquiries, or discuss or comment on the quality and content of the website (Perez-Lopez and Perez-Roncero, 2006). This demonstrates willingness to serve and take into consideration feedback from the users. Navigability examined how easy it was to obtain information and follow links, an important feature, as poor navigability may cause the visitors to leave the site.

The content quality features of subject depth, disclosure of authorship and sources of information, credibility of source, and neutrality, were the major determinants of website quality as assessed in this study. Evaluation of subject depth took into account the context and purpose of the site. Disclosure of authorship, including the author's credentials and qualifications is necessary for transparency and accountability (Metzger, 2007). Its presence is deemed ethical according to several codes of conduct for web publishing (Eysenbach et al., 2002). Disclosure of source of information (e.g., references, contact addresses) is similarly critical to allow for verification and follow up. The neutrality of some websites was affected by use of inflammatory language or extreme or unsubstantiated claims, either for or against application of plant biotechnology.

Frequency of update did not have a significant correlation with the quality of website in these analyses. This is contrary to a previous study intending to identify a simple screening criterion for quality of websites dealing with genetically modified food, which indicated that frequency of update, also commonly referred to as currency, was a criterion of primary importance, accounting for over 20% of the variance in the quality score (McInerney and Bird, 2005). While it is especially crucial in a rapidly changing field such as biotechnology to know where current information exists, our analyses did not show frequency of update to be as important in quality determination compared to other factors such as credibility of source, declaration of authorship and neutrality. This may be because, depending on the need, older postings can provide highly relevant background information.

Affiliation or ownership significantly influenced the general and content quality of the website. Government and university/research institute affiliated sites were found to have higher content quality than those associated with commercial or non-profit organisations/NGOs. This agrees with previous studies which suggested that website ownership may be a predictor for content quality, with commercial sites often scoring lower than academic sites (Eysenbach et al., 2002, Lissman and Boehnlein, 2001). This higher score is often influenced by quality criteria such as disclosure of author and source (Griffiths and Christensen, 2000; Veronin and Ramirez, 2000) which was more common on sites owned by scientists/professionals, academicians or governments.

Regardless of the keyword used as a search term, many of the websites (12 or more of the top 25) retrieved are likely to be advertisements or scientific peer reviewed journal articles with a narrow topic focus that may not provide general information about plant biotechnology. Most of the best websites related to plant biotechnology may only rarely be accessed by the public because they do not appear in the top-ranked websites for search engines like Google. These results should help raise awareness of internet users to some of the good quality websites for obtaining information on plant biotechnology (Table 8) and suggest to website developers terminologies that may help target the desired audience.

5 Conclusions

With more than two billion individuals worldwide now accessing the internet (Internet World Stats, 2011) the internet has become a very useful resource for meeting some of the public's information needs. A number of high quality websites providing information about plant biotechnology and genetically engineered crops are available, as indicated above. However, accessing reliable, high-quality information, especially about a controversial topic such as genetically modified organisms, is not always easy. The findings of our study provide insight into the way in which the public searches for information. In the interest of ensuring accurate public awareness, responsible stakeholders need to find ways to make high quality information more accessible on the web. They should understand how site ranking is done and employ terms that the intended audience will most likely use when searching. While the information provided here indicates which websites are obtained with which search term, it also can provide insight into which terms a website should use if it would like to attract viewers from a particular subcategory (e.g., scientists, general public), or a from a specific country, based on what terms those groups are likely to use in initiating their inquiry.

Wherever and whenever possible the most appropriate websites should be recommended by information providers. It is also important that credible website producers present well-organised information in a way that allows for easy access, since poor navigability may discourage visitors from browsing the site. They also should establish mechanisms for routinely rating their websites and encourage feedback about various attributes of the websites and information. Finally, there is need for further studies to analyse and identify gaps in existing internet information on the topic, as this may guide priorities for future public communication on plant biotechnology.

References

- Anderson, A.A., Brossard, D. and Scheufele, D.A. (2010) 'The changing information environment for nanotechnology: online audiences and content', *Journal of Nanoparticle Research*, Vol. 12, No. 4, pp.1083–1094.
- Eachus, P. (1999) 'Health information on the internet', *International Journal for Health Promotion and Education*, Vol. 37, No. 1, pp.30–33.
- Eysenbach, G., Powell, J., Kuss, O. and Eun-Ryoung, Sa. (2002) 'Empirical studies assessing the quality of health information for consumers on the world-wide web', *Journal of the American Medical Association*, Vol. 287, No. 20, pp.2691–2700.

- Google (2009) 'Google corporate information', available at <http://www.google.com/corporate/tech.html> (accessed on 10 December 2009).
- Griffiths, K.M. and Christensen, H. (2000) 'Quality of web based information on treatment of depression: cross sectional survey', *British Medical Journal*, Vol. 321, No. 7275, pp.1511–1515.
- Health on the Net (HON) Available at <http://www.hon.ch/> (accessed on 9 June 2008).
- Internet World Stats (2011) Available at <http://www.internetworldstats.com/stats.htm> (accessed on 21 July 2011).
- James, C. (2011) 'Global status of commercialized biotech/GM crops: 2010', Executive summary, ISAAA Briefs No. 42, International Service for the Acquisition of Agri-biotech Applications, Ithaca NY.
- Ladwig, P., Anderson, A.A., Brossard, D., Scheufele, D.A. and Shaw, B. (2010) 'Narrowing the nano discourse?', *Materials Today*, Vol. 13, No. 5, pp.52–54.
- Lissman, T.L. and Boehnlein, J.K. (2001) 'A critical review of internet information about depression', *Psychiatric Services*, Vol. 52, No. 8, pp.1046–1050.
- Low, F.C. and Frederick, R.J. (2011) 'The Cartagena protocol on biosafety and other international regulations', in Grumet, R., Hancock, J.F., Maredia, K.M. and Weebadde, C. (Eds.): *Environmental Biosafety of Genetically Engineered Crops*, pp.131–145, Michigan State University Press, East Lansing MI.
- McInerney, C.R. and Bird, N.J. (2005) 'Assessing website quality in context: retrieving information about genetically modified food on the web', *Information Research*, Vol. 10, No. 2, Paper 213, available at <http://informationr.net/ir/10-2/paper213.html>.
- Metzger, M.J. (2007) 'Making sense of credibility on the web: models for evaluating online information and recommendations for future research', *Journal of the American Society for Information Science and Technology*, Vol. 58, No. 13, pp.2078–2091.
- Perez-Lopez, R.F. and Perez-Roncero, R.G. (2006) 'Assessing the content and quality of information on the treatment of postmenopausal osteoporosis on the World Wide Web', *Gynecological Endocrinology*, Vol. 22, No. 12, pp.669–675.
- Search Engine Watch (2011) 'June 2011 search engine market share', available at <http://searchenginewatch.com/article/2094160/June-2011-Search-Engine-Market-Share-from-comScore-Hitwise> (accessed on 21 July 2011).
- Silberg, W.M., Lundberg, G.D. and Musacchio, R.A. (1997) 'Assessing, controlling, and assuring the quality of medical information on the internet', *Journal of American Medical Association*, Vol. 277, No. 15, pp.1244–1245.
- Spink, A. and Cole, C. (2001) 'Introduction to the special issue: everyday life information-seeking research', *Library and Information Science Research*, Vol. 23, No. 4, pp.301–304.
- Traynor, P.L., Adonis, M. and Gil, L. (2007) 'Strategic approaches to informing the public about biotechnology in Latin America', *Electronic Journal of Biotechnology*, Vol. 10, No. 2, pp.169–177.
- Veronin, M.A. and Ramirez, G. (2000) 'The validity of health claims on the World Wide Web', *American Journal of Health Promotion*, Vol. 15, No. 1, pp.21–28.