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Disciplines
Library and Information Science

Comments
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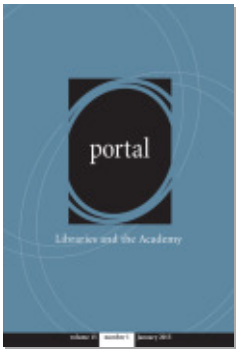

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abstract: This article reports the findings of a study conducted to examine the types of information used by graduate students in the fields of biological and agricultural sciences at Iowa State University (ISU). The citations of doctoral dissertations submitted in nine agriculture and biological science subject fields (crop production and physiology; molecular, cellular, and developmental biology; entomology; genetics; microbiology; plant breeding; plant pathology; plant physiology; and soil science) at ISU from 1997–2006 were analyzed. The article discusses the types and ages of resources cited in the different subject fields studied. The most cited journals in each discipline were identified, and the journal title dispersion was examined.

This is a revolutionary time in biological sciences and related disciplines. Although many different subfields are emerging, interdisciplinary research collaborations among these subfields are increasing. The knowledge bases of biological and agricultural sciences are expanding at an unprecedented rate. This phenomenon is clearly reflected by the ever-increasing number of journals published in these subject areas. Academic research libraries face the daunting task of meeting the information needs of researchers in these scientific disciplines at a time that scientific journal and monograph costs are increasing, and library acquisition budgets are staying flat. To provide the library collections that academic users demand, librarians need a clear understanding of the information needs, information-seeking behavior, and information use of their user communities. Collection development decisions should be based on facts rather than on perceptions and assumptions.

Librarians and information professionals have often relied on "information use" as a measure of "information needs" of user communities. Although the broader meaning of "information use" encompasses more than the citation behavior of information users

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as Marian Burright, Trudi Bellardo Hahn, and Margaret J. Antonisse acknowledged, citation analysis has been used to examine the information use of scholars.[1] Librarians often use citation analysis methodology to assess collection needs, and there is a considerable body of literature describing how citation analysis has been used to identify the core journals of a discipline. According to Linda Smith, "Citations are signposts left behind after information has been utilized and as such provide data by which one may build pictures of user behavior without ever confronting the user himself."[2] Sherri Edwards described citation analysis as "a procedure of counting and ranking the number of times documents are cited in bibliographies, footnotes, and/or indexing tools."[3] Citation analysis has both merits and limitations as a collection development tool. In her article "Citation Analysis," Smith discussed the underlying assumptions of citation analysis and the problems associated with it.[4]

Citation analysis, when used as a collection development tool, can be placed into one of two broad categories: global or local. Global citation analysis is used to examine information use, especially journal and monograph usage patterns, within a discipline. Steve Black conducted a global citation analysis study to identify a core journal collection in communication disorders by examining every citation in all issues of two journals over a three-year period.[5] Chad Buckley used citation analysis of monographs cited in selected issues of a core journal in conservation biology between 1987 and 1996 to identify important monographs in the field.[6] Louise Zipp described a study conducted to identify a core list of journals for environmental geology, an interdisciplinary discipline bridging the larger fields of environmental science and geology.[7]

Despite their value in understanding the literature of a particular discipline, global citation analysis findings may not be useful or relevant for individual libraries as a basis for collection management decisions.[8] Harry Kritz argued that "a library must serve the local group of authors, not a subject field. Thus, a librarian needs to know what is being used and cited by those who use the library, not what is being cited by those who publish in a particular set of journals."[9] He further noted that studies of literature in a discipline provide a general measure of information sources used by professionals in the field, but students' use within a discipline may differ from that of professionals.[10] Therefore, librarians should conduct local citation analysis studies to examine the literature use of their local communities such as researchers in a specific discipline in a university or an organization in order to understand their information needs.[11]

When citation analysis is used as a tool for the development of journal collections, one useful metric to examine is journal title dispersion. Rolland Stevens defined title dispersion as "the degree to which the useful literature of a given subject area is scattered through a number of different books and journals."[12] The title dispersion is low if a large portion of the cited literature is from a few journals and high if cited references are scattered among many journals. Many citation analysis studies have revealed that, within an academic discipline, the journal title dispersion is low; in other words, the majority of citations are contained in a few core journals. Stevens summarized early work done between 1930 and 1944 on title dispersion in a variety of science disciplines, including chemistry, physics, biochemistry, chemical engineering, electrical engineering, and radio engineering.[13] Among the studies he discussed was the pioneering one conducted by P. L. K. Gross and E. M. Gross (1927) who examined literature in the field of chemistry.

According to their work, 25 percent of the literature citations were from two journals, 50 percent of the citations were from seven journals, and 75 percent of the citations were from 24 journals. In all of the studies of science and technology disciplines included in Stevens' discussion, 25 percent of the citations were contained within one to three journals.[14] The title dispersion increases, however, when the interdisciplinary nature of the discipline increases. According to Stevens, title dispersion is greater for technology fields than it is for pure science fields. Joy Thomas also found greater dispersion in her study of psychology theses; 80.8 percent of the citations came from 80 percent of the total journals cited.[15] Understanding the journal title dispersion within both well-established disciplines and new and emerging disciplines may help librarians to manage journal collections more effectively.

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A considerable portion of a research program in a research university is comprised of projects conducted by graduate students. Therefore, examining graduate student information needs and information use will undoubtedly help librarians in research universities to develop the library collections needed to support the research mission of their institution. Doctoral students usually conduct comprehensive literature reviews in their research areas, making dissertations a rich source of bibliographic information for librarians in academic research libraries. In addition, dissertations provide information about research trends in their respective subject disciplines and academic institutions. Anne Buchanan and Jena-Pierre Herubel emphasized the need for subject bibliographers to examine dissertation citations, both to understand the trends in dissertation research and to maintain a collection capable of supporting doctoral-level research programs.[16] Because of this, more and more studies are being conducted to examine the citations contained within graduate student dissertation reference lists. Dissertation and thesis citation studies done in science and engineering disciplines since 1990 are presented in the endnotes.[17]

Citation analysis can also be considered as an unobtrusive method to determine the information sources doctoral students use for their research projects. Although the majority of dissertation citation analysis studies focus on identifying core lists of journals and monographs in subject disciplines, the findings of these studies often provide useful information for subject librarians' understanding of the information needs and uses of graduate students. This understanding may help subject librarians to create discipline-specific subject guides, library research guides, and help department liaison librarians to communicate more effectively with their respective subject departments. Laurel Haycock suggested that citation analysis data can be used as documentation support for material selection decisions, resulting in fiscal accountability.[18]

Objective

The purpose of the current study was to examine the literature used in graduate research in agricultural and biological sciences and to identify citation pattern variations

that exist among subject fields within these major disciplines. The study was designed to answer the following questions about the information resources used by graduate students in agricultural and biological sciences for their doctoral research at Iowa State University:

- What formats of materials are used by doctoral students in agricultural and biological science subject fields? Is there a difference in material formats used among subject fields?
- How do citation patterns vary among these subject fields?
- What are the most frequently cited journals in different subject fields of agricultural and biological sciences? What are the journal title dispersion patterns within each of the subject fields?

Setting

Founded in 1858 as the first land grant institution in the United States, Iowa State College of Agriculture and Mechanic Arts became the Iowa State University of Science and Technology (ISU) in 1959. ISU is categorized as a Carnegie Doctoral/Research-Extensive University and is a leader in science and technology research, particularly in agricultural and biological sciences. The College of Agriculture, recently renamed the College of Agriculture and Life Sciences, includes the biological and agricultural science departments. Agricultural science programs at ISU offer undergraduate and graduate majors in disciplines such as agronomy, agricultural systems technology, dairy science, food science, horticulture, entomology, plant pathology, and agricultural education. The agriculture disciplines are increasingly involved in interdisciplinary study and research and leading edge technology. ISU was the thirteenth most cited institution in the world for research papers in agricultural sciences from 1998 through 2008, illustrating the strength of the ISU agricultural research program.[19] Biological sciences programs at ISU were reorganized in 2002 to bring together scholars with similar research interests and methodologies and to reform the curricula to reflect the increasingly interdisciplinary nature of research in the biological sciences.

Biological science majors at ISU include a broad range of areas such as microbiology, neuroscience, and agricultural biochemistry. Increasingly, interdepartmental majors are offered, particularly at the graduate level, in fields such as plant physiology and environmental science. Research foci recognized as particularly strong at ISU include genetics, agricultural biotechnology, and bio-renewable resources.

Methodology

This study covered dissertations submitted in nine agriculture and biological sciences disciplines at the Iowa State University from 1997–2006. Subject disciplines examined in the study included five agricultural subject fields (crop production and physiology [CP&P], entomology, plant breeding, plant pathology, and soil science) and four biological science fields (genetics; microbiology; molecular, cellular, and developmental biology [MCDB]; and plant physiology). A list of PhD recipients of the departments in

the College of Agriculture was obtained from the Office of the Registrar at ISU. When available, two dissertations per year for each of 10 years (from 1997–2006) were randomly selected within each subject discipline.

The title page, table of contents, and reference section of each selected dissertation was printed. Demographic data (department, major, publication date, and total number of citations) for each dissertation were recorded. Each citation title was categorized into one of 19 format groups (see table 1). Unknown titles and abbreviated journal titles were verified when possible using OCLC or Ulrich's *International Periodicals Directory*; titles that could not be verified were included in the "questionable" category. Each periodical cited in at least one dissertation was counted and listed to identify the most frequently cited periodicals. Using these data, periodical title dispersion values were calculated for each subject field. To determine the age distribution of citations, every fifth citation within each dissertation was selected. The age of the chosen citations was calculated as the number of years between publication of the cited reference and acceptance of the dissertation in which it was cited.

Results

A total of 154 out of 333 dissertations published between 1997 and 2006 in nine biological and agricultural science subject fields were examined in this study. As noted, whenever possible, two dissertations per subject field per year were randomly selected. However, because of the limited number of dissertations published in some disciplines, selection of two dissertations per year per subject field was not always possible. A total of 29,894 citations were examined in the study. The number of citations for each subject field and the average number of citations per dissertation for each discipline are given in table 2.

Average Number of Citations per Dissertation

Of the 29,894 citations, 80.5 percent were journals, 10.5 percent were monographs, and 8.9 percent were in other formats (see table 3). Figure 1 shows the average number of journal citations per dissertation for each subject field. The average number of journal citations per dissertation for MCDB, microbiology, genetics, and plant physiology disciplines varied from 191.4 to 213.4, whereas the average number of journal citations per dissertation in plant pathology, entomology, plant breeding, and soil science ranged from 93 to 157.5.

Figure 2 shows the citations of monographs and "other" formats by subject field. The lowest number of monographs per dissertation was cited in MCDB, and the highest number was in soil science. Genetics and MCDB dissertations included the lowest number of citations in "other" formats, whereas entomology and plant pathology dissertations included the highest number of citations in this category (see figure 2).

Microbiology, plant pathology, entomology, plant breeding, soil science, and CP&P dissertations included the largest variety of citations categorized in the "other" format category (see figure 3).

Table 1
Format Categories

Periodical—"A serial appearing or intended to appear indefinitely at regular or stated intervals, generally more frequently than annually, each issue of which is numbered or dated consecutively and normally contains separate articles, stories, or other writings. Newspapers disseminating general news, and the proceedings, papers, or other publications of corporate bodies primarily related to their meetings, are not included in this term."*

Monograph—"In cataloging, a non-serial bibliographic item, i.e., an item either complete in one part or complete, or intend to be completed, in a finite number of separate parts."**

Other
Bulletins & newsletters
Computer programs
Conference proceedings
Dissertations and theses
Experiment station publications
Extension publications
Government publications
Guides, manuals, and handbooks
In press—articles that were accepted but not yet published
Miscellaneous—leaflets, newspaper articles, personal communications
Patents
Questionable—all the citation titles that could not be verified
Reports
Standards
Symposium abstracts/presentation—conference presentations and published abstracts of presentations
Unpublished—articles in preparation, submitted, or under review
Web sites

* The term "journal" will be used instead of the term "periodical" in the rest of this article.
** Heartsill Young, ed., *ALA Glossary of Library and Information Science* (Chicago: American Library Association, 1983), 166, 148.

Table 2
Citations by Subject Field

Subject field	Number of dissertations	Number of citations	Average number of citations per dissertation
Crop Production and Physiology (CP&P)	18	3027	168.2
Entomology	16	2532	158.3
Genetics	20	4761	238
Microbiology	18	4529	251.6
Molecular, Cellular and Developmental Biology (MCDB)	17	3479	204.6
Plant Breeding	20	3060	153
Plant Pathology	11	2261	205.5
Plant Physiology	14	2921	208.6
Soil Science	20	3324	166.2
Total	154	29894	194.9

Table 3
Format of Cited Materials

Format	Number of citations	% of citations
Journals	24072	80.5
Monographs	3152	10.5
Other	2670	8.9
Proceedings	568	
Guides, Handbooks, Manuals	338	
Questionable	281	
Dissertations/Theses	270	
Bulletins & Newsletters	229	
Extension Publications	149	
Unpublished	138	
Web sites	129	
Experiment Station Publications	112	
Symposium abstracts and presentations	108	

Table 3, continued.

Format	Number of citations	% of citations
Other		
Reports	95	
In Press	81	
Computer Programs	78	
Miscellaneous	36	
Gov. Publications	30	
Patents	25	
Standards	3	
Total	29894	

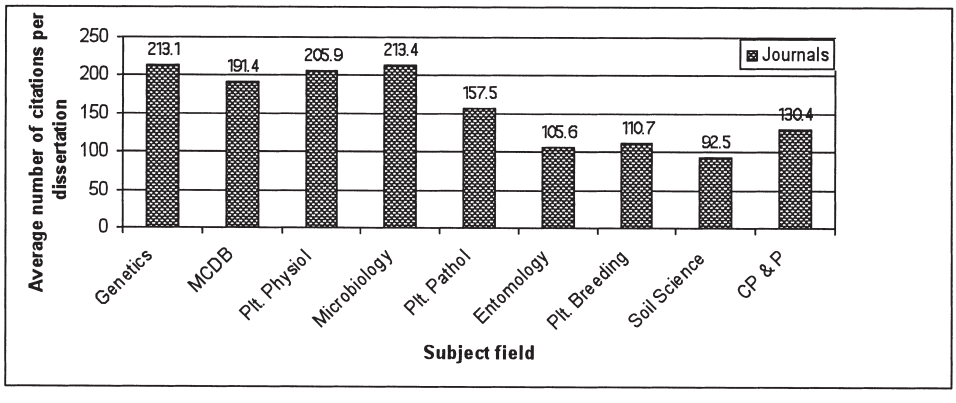

Figure 1. Number of journal citations by subject field.

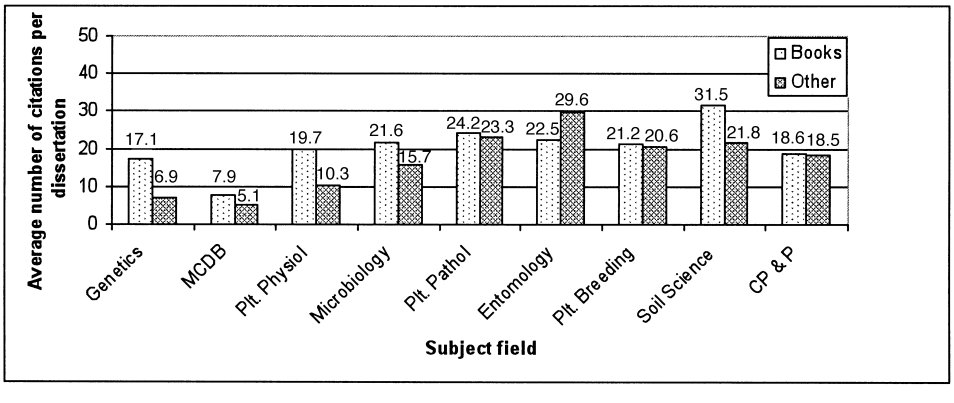

Figure 2. Number of monographs and "other" citations by subject field

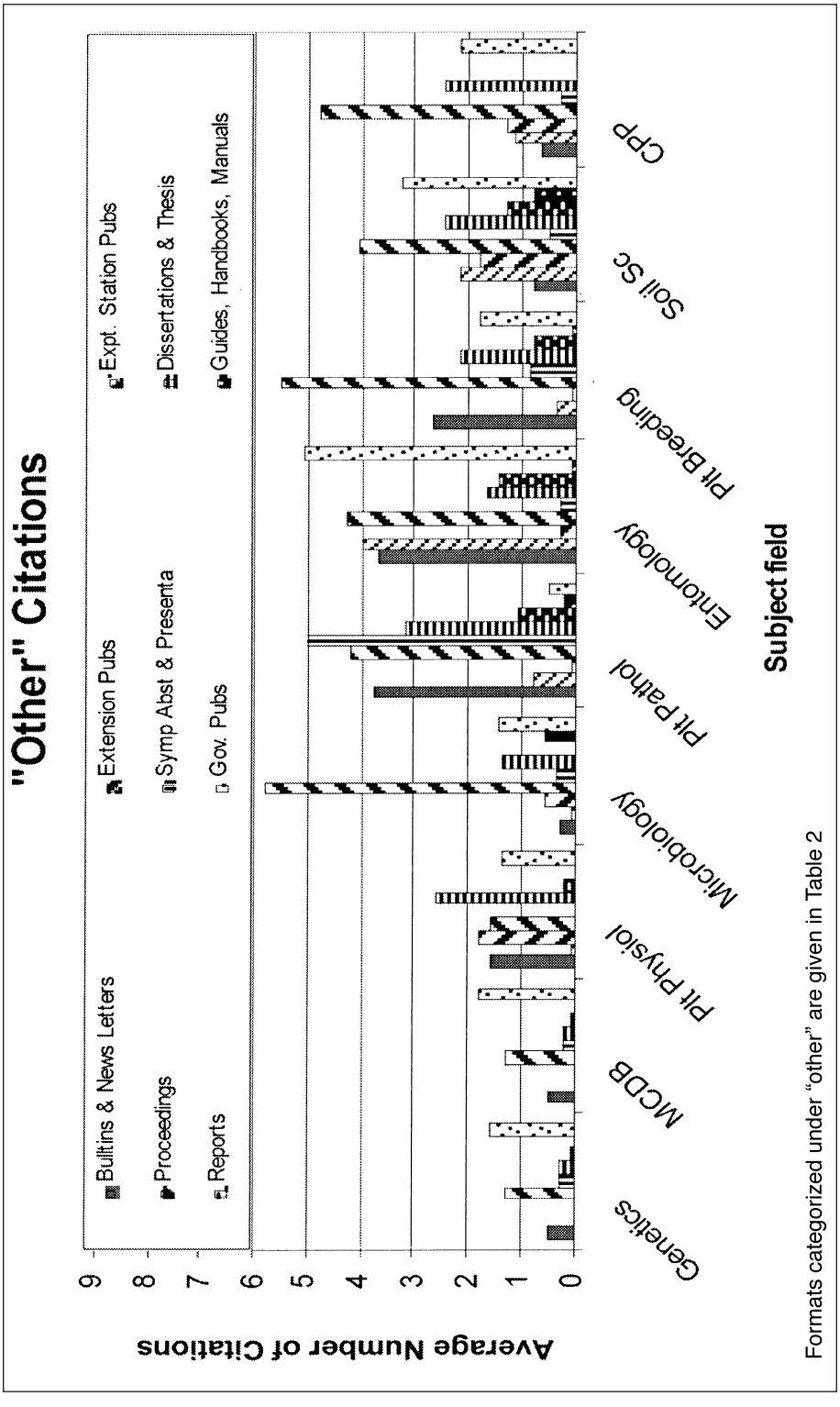

Figure 3. Number of citations of "other" formats by subject field.

Citation Age

Half of the citations observed in the study were less than seven years old, and 90 percent of the citations were less than 24 years old. The oldest citation was 173 years old and was cited in a plant pathology dissertation; a 156 year-old citation was cited in a molecular, cellular, and developmental biology dissertation; and a 117 year-old citation was found in an entomology dissertation. Results showed that most of the references cited (across all subject fields) fell within the two- to five-year age range. Figure 4 shows the citation age distribution in three agricultural science subject fields (crop production and physiology, plant breeding, and soil science) and three biological science subject fields (genetics; molecular, cellular, and developmental biology; and microbiology). Figure 5 shows how the average age of citations varies among nine subject fields examined. Dissertation citation ages were lower in biological science fields than in agricultural science subject fields. Results also revealed that 70 percent of the citations were less than nine years old in biological science subject fields and less than 15 years old in agricultural science subject fields; 90 percent of citations were less than 17 years old in biological science subject fields and less than 29 years old in agricultural science subject fields. Citations older than 30 years were more prevalent in agricultural sciences than in biological sciences (see figures 4 and 5).

Results showed that most of the references cited (across all subject fields) fell within the two- to five-year age range.

Journal Usage Trends

Longitudinal trends in journal and monograph usage in these subject fields were examined by dividing the 10-year period into five two-year blocks. The percentages of journal and monograph citations were calculated and plotted over time. The highest journal usage (as a percent of total citations) was observed in MCDB over the test period, and journal usage was consistently high in genetics and plant physiology. Journal usage was lower over the years in soil science, plant breeding, and entomology. A reduction

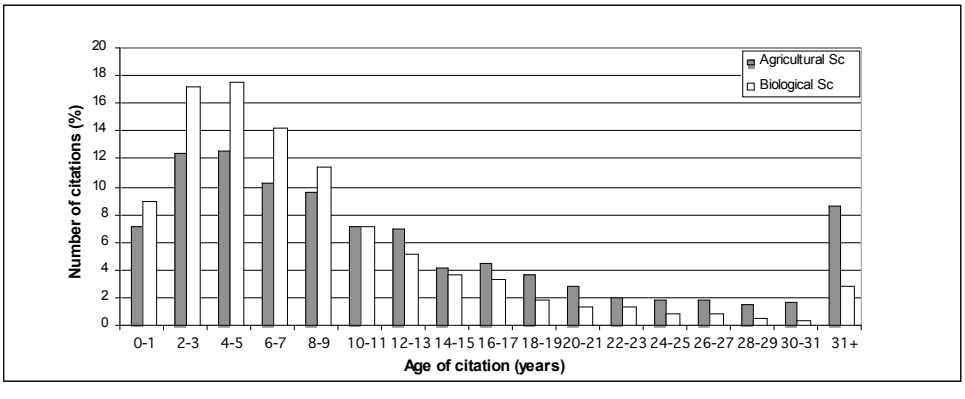

Figure 4. Citation age distribution in agricultural sciences and biological sciences.

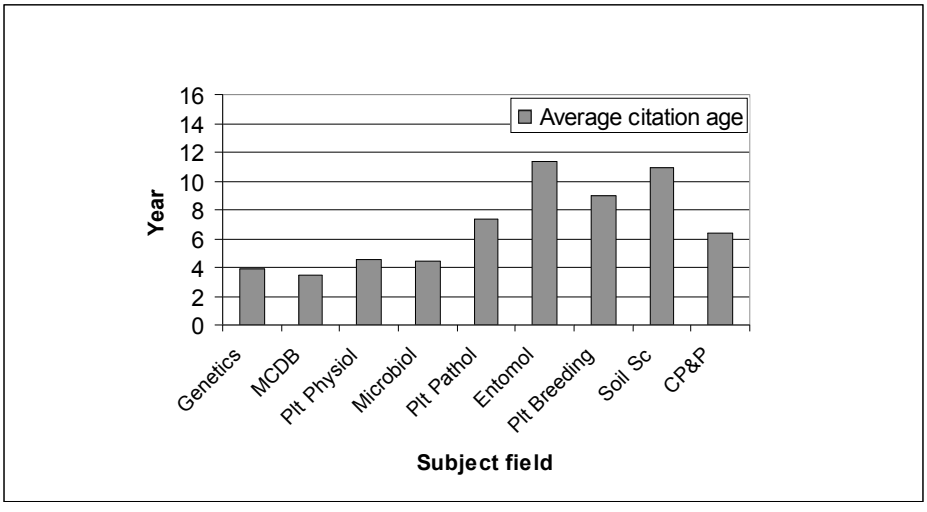

Figure 5. Average citation age (in years) by subject field.

in journal usage relative to other citation formats was observed in plant pathology and crop production and physiology (CP&P) over the 10-year period (see figure 6). Monograph usage from 1997 to 2006 either did not change considerably or showed marked fluctuations, depending on the subject discipline. Monograph usage was consistently low in MCDB during this time period.

Most Cited Journals by Subject Field

Table 4 includes the 10 most cited journals by the doctoral students in each of the agricultural and biological sciences subject fields examined. The ISU library provides

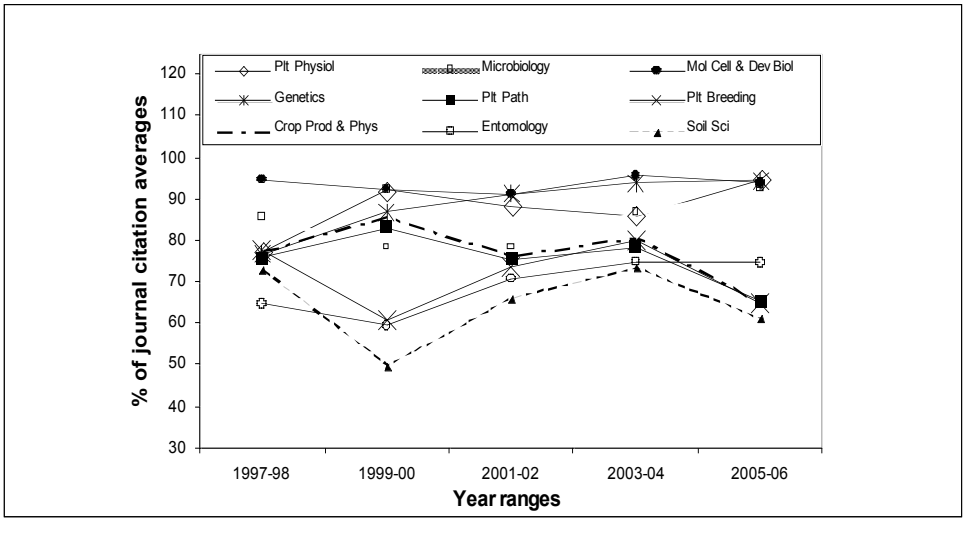

Figure 6. Journal usage trends from 1997 to 2006.

Table 4

Most Cited Journals by Discipline

Crop Production & Development
Crop Science
Agronomy Journal
Plant Physiology
Weed Science
Soil Science Society of America Journal
Weed Technology
Plant Molecular Biology
Seed Science Research
Journal of Ecology
Planta

Soil Science
Soil Science Society of America Journal
Agronomy Journal
Biology and Fertility of Soils
Soil Science Society of America Proceedings
Soil Biology & Biochemistry
*Soil Science**
Journal of Environmental Quality
Communications in Soil Science and Plant Analysis
*Canadian Journal of Soil Science**
New Phytologist

Plant Breeding
Crop Science
Theoretical and Applied Genetics
Genetics
Communications in Soil Science and Plant Analysis
Genetical Research
Maydica
Plant Physiology
Critical Reviews in Food Science & Nutrition
Agronomy Journal
Soybean Digest

Entomology
Journal of Economic Entomology
Environmental Entomology
Plant Disease
American Journal of Tropical Medicine & Hygiene
Phytopathology
Annals of Entomological Society of America
Journal of Medical Entomology
Proc. Natl. Acad. Sci. U. S. A. (PANS)
Journal of Invertebrate Pathology
Crop Science

Plant Physiology
Plant Physiology
Plant Cell
Plant Journal
Proc. Natl. Acad. Sci. U. S. A. (PANS)
Journal of Biological Chemistry
Planta
Plant Molecular Biology
Crop Science
Journal of Experimental Botany
EMBO Journal

Genetics
Proc. Natl. Acad. Sci. U. S. A. (PANS)
Genetics
Plant Cell
Cell
Journal of Biological Chemistry
Plant Physiology
Science
EMBO Journal
Molecular and Cell Biology
Journal of Virology

Molecular, Cell and Developmental Biology
Cell
Journal of Biological Chemistry
Proc. Natl. Acad. Sci. U. S. A. (PANS)
Science
Nature
Molecular and Cell Biology
Journal of Virology
Genes and Development
Journal of Cell Biology
Plant Physiology

Microbiology
Journal of Bacteriology
Applied Environmental Microbiology
Infection and Immunology
Proc. Natl. Acad. Sci. U. S. A. (PANS)
Veterinary Microbiology
Molecular Microbiology
Journal of Veterinary Diagnostic Investigation
Veterinary Record
Journal of Biological Chemistry
American Journal of Veterinary Research

Plant Pathology
Phytopathology
Plant Disease
Journal of Nematology
Remote Sensing of Environment
Agronomy Journal
Virology
Crop Science
Mycologia
Journal of Virology
Canadian Journal of Plant Pathology

online access to all but two of these journals. Of these most cited journals, 15 were cited in more than one subject field. *Crop Science,* the most frequently cited journal, was cited 901 times; and the second most frequently cited journal, *Plant Physiology*, was cited 844 times. Both of these journals were cited by the largest number of subject fields (five subject fields). Table 5 shows the names of these journals and number of times they were cited in different subject fields.

Journal Title Dispersion

The journal title dispersions in these subject fields were examined by identifying the number of titles needed to satisfy 25 percent, 50 percent, 75 percent, and 100 percent of the journal citation needs in each field. Within the nine subject fields examined, 25 percent of citations were contained within three to seven journals, 50 percent within eight to 24 journals, 75 percent within 28 to 77 journals, and 100 percent within 245 to 481 journals (see table 6).

The lowest citation dispersion was observed in the field of plant breeding, and the highest dispersion was in microbiology. Dissertations in microbiology were completed in several different subject departments: microbiology, immunology and preventive medicine (1996–1998), agronomy, plant pathology, entomology, animal science, biochemistry, biophysics, molecular biology, and food science and human nutrition. The interdisciplinary nature of the subject field explains the higher journal title dispersion in microbiology.

Discussion

Although agricultural and biological sciences are two closely related major disciplines with overlapping knowledge bases, researchers may have differences in their information needs and information use within these two broad disciplines. Subject specialist librarians in these areas need to understand these similarities and differences not only to manage library collections but also to provide library instruction and create discipline-specific subject guides and library research guides. The current study examined the information use patterns in graduate research projects across nine subject fields within agricultural and biological science programs at ISU.

According to the findings of this study, the average number of citations per dissertation is lower in agricultural science subject fields than in biological science subject fields. The study revealed that, regardless of the subject field, "journal" was the most cited format. However, the relative frequencies of journal citations were higher in biological science subject fields than in agricultural science subject fields.

Because electronic databases have become more prevalent since the mid-1990s, it was assumed that over the 1997–2006 time period chosen for this study, the graduate student population would have become increasingly more comfortable using electronic databases for their literature searches. For that reason, some changes in information use patterns were anticipated. Surprisingly, this study did not show a clear change in journal and monograph citation patterns over this time period.

Table 5

Journals Cited in More Than One Subdiscipline

Journal	Number of citations in each subject field[b]								
	CP &P	Plant Breeding	Soil Science	Entomol.	Plant Pathol.	MCDB	Genetics	Plant Physiol.	Total
Crop Sci	274	490	-	31	37	-	-	69	901
Plant Physiology	136	46	-	-	-	86	144	432	844
Proc. Natl. Acad. Sci. USA	-	-	-	45	-	156	323	155	679
Agronomy J.	280	43	189	-	53	-	-	-	565
J. Biol Chem	-	-	-	-	-	247	147	142	536
Plant Cell	-	-	-	-	-	-	154	270	424
Cell	-	-	-	-	-	257	149	-	406
Phytopathology	-	-	-	54	335	-	-	-	389
Plant Disease	-	-	-	63	310	-	-	-	373
Genetics	-	133	-	-	-	-	229	-	362
Science	-	-	-	-	-	142	136	-	278
Mol. Cell Biol.	-	-	-	-	-	133	129	-	262
J. Virol	-	-	-	-	37	101	115	-	253
EMBO J	-	-	-	-	-	-	130	57	187
Common Soil Sci Plant Anal	-	62	48	-	-	-	-	-	110

[b] Number of dissertations used in different subject fields are given in the table 2.

Table 6

Journal Title Dispersion in Different Subject Fields

% of citations	CP&P	Plant Breeding	Soil Science	Entomology	Plant Pathology	Microbiol.	MCDB	Genetics	Plant Physiology
25	3	3	3	3	3	7	4	6	5
50	11	12	7	8	8	24	12	14	17
75	53	37	32	28	42	77	40	43	56
100	306	245	253	285	285	481	305	322	381

Examination of citation age revealed that graduate students in both agricultural and biological science subject fields consulted relatively recent literature for their research; however, graduate students in agricultural sciences tended to consult older literature more often than did graduate students in biological science subject fields. This trend reflects the dynamic nature of biological sciences subject fields. The 10 most cited journals within each subject field were identified (see table 4).

When these lists were compared across subject areas, 15 journals were found to be among the 10 most frequently cited in more than one subject field. The journals cited across the greatest number of subject areas were *Crop Science* and *Plant Physiology*. *Crop Science* was cited in CP&P, plant breeding, entomology, and plant physiology; and *Plant Physiology* was cited in CP&P, plant breeding, MCDB, genetics, and plant physiology. Seven journals (*Cell*, *Journal of Biological Chemistry*, *Journal of Virology*, *Molecular and Cellular Biology*, *Plant Physiology*, *Proceedings of the National Academy of Sciences U.S.A.*, and *Science*) were among the 15 most cited journals in both genetics and MCDB. *Plant Physiology*, *Proceedings of the National Academy of Sciences U.S.A*, and *Journal of Biological Chemistry* were cited by MCDB, genetics, and plant physiology. These findings illustrate the interdisciplinary nature of the genetics and MCDB research programs at ISU. The most cited journal in agricultural science dissertations was *Crop Science*, and *Plant Physiology* was the most cited journal in biological science dissertations.

The title dispersion of all the subject fields examined in the current study can be considered low. In soil science, 100 percent of the journal citations were contained within 253 journals; in plant breeding, within 245; in MCDB, within 305; in CP&P, within 306; and in genetics, within 322. Out of the nine fields examined, microbiology had the highest title dispersion: 481 journal titles were needed to cover 100 percent of the citations. To cover 75 percent of the citations, only 29–77 journal titles were needed for entomology, soil science, plant breeding, MCDB, genetics, CP&P, and microbiology. The results of the current study are consistent with the findings of other citation analysis studies, indicating that a relatively small number of journal titles can cover the majority of journal needs in scientific disciplines.[20]

The title dispersion of all the subject fields examined in the current study can be considered low.

Although monographs and resources in other formats are not as important as journals, results of this study revealed the value of access to literature in a variety of formats, especially for certain subject fields in agricultural sciences. For example, entomology dissertations had an average of 22.5 monographs and 29.6 citations in "other" formats. Not only were a higher number of "other" formats cited in agricultural science subject fields than in biological science subject fields but also the range of formats cited was greater. Because of the importance of literature in formats such as reports, bulletins, newsletters, agricultural extension publications, and experimental station publications for agricultural science, the need to provide easy access to these resources by preserving and archiving them has to be highlighted.

In a research university, the graduate student population is an important library user group. Librarians have used a variety of strategies to examine needs of this user

group, and dissertation citation analysis is becoming more popular in this regard. Although dissertation citation analysis has many advantages, it is important to be aware of its inherent limitations when used as the basis of predicting information use by graduate students in their research projects. The main limitation is that dissertation or thesis citation data reflect only the sources actually cited, not all the sources consulted during the research process. The underlying assumption of dissertation citation analysis is that the graduate students will obtain and use the best sources needed for their research work. However, because of their limited information research skills and lack of awareness of the available library resources, some graduate students might choose readily available materials over more important material not locally held, leading to a "threatening self-perpetuating cycle," as stated by Haycock.[21] Another concern is that some students might add citations to increase the length or perceived scholarliness of their dissertations.[22] Although unobtrusiveness of the data collection increases the validity of citation analysis results, inaccuracy of the information found in some citations negatively affects the validity of results. Since citation analysis results may not give a complete picture of the information use of the graduate student user group, citation analysis results should not be used as the sole basis for collection management decisions but used instead in combination with other indicators of information use.

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Conclusion

As John Ziman stated, a scientific publication does not stand alone, but is "embedded in the 'literature' of the subject."[23] The citing of a scientific publication gives an indication of the influence of the publication. Citation analysis is a tool that can help provide an understanding of this influence across multiple publications within a user group or scientific discipline.

This study has provided a good understanding of the influence of different formats and ages of literature on the research projects of a group of budding scientists in agricultural and biological sciences. This will help subject librarians in agricultural and biological sciences at ISU make subject-specific collection management decisions. For example, the prevalence of monographs and publications in "other" formats within applied science disciplines is an important factor to consider in library collection development in these subject areas. The results of this study confirm the findings of previous citation studies, which have shown that the majority of citations in academic subject areas are contained within a small number of journals. However, in some subject fields (for example, microbiology) the number of journal titles needed to cover the majority of citations is higher. This kind of subfield-specific information can be very useful for subject librarians to consider when making journal collection management decisions.

Combining the results of our study, which focused on information use by student researchers, with citation analysis of articles published by more experienced researchers

would give a fairly complete picture of information use patterns in these agricultural and biological science disciplines. As the logical follow-up to this study, a citation analysis of articles published by ISU researchers and faculty members in these subject areas is currently being planned.

Although this local citation analysis study examined dissertations published only at Iowa State University, these findings should help subject librarians in other universities to understand the information resource needs of graduate students in agricultural and biological sciences.

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