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Journal Citation Studies. 53. Agricultural Sciences: Most Fruitful Journals and High Yield Research Fields

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Citation data for agricultural science journals indexed in the 1989 *Science Citation Index*® are examined. Impact factors, journals most cited by these "core" journals, and those that most frequently cited the core journals are identified. Highest impact articles and most active research fronts in the agricultural sciences also are presented. Based on these data, nine journals are identified as occupying a prominent position in the field.

Introduction: A Brief Overview of Agriculture

Last October, I participated in a symposium on peer review and editing at the annual meeting of the American Society of Agronomy (ASA) in San Antonio, Texas. At the invitation of Bob Sojka and Hank Mayland, Agricultural Research Service, US Department of Agriculture (USDA), Kimberly, Idaho, I presented a citationist perspective on how the ASA's key publications compare with other journals of agricultural research.[1] While this presentation understandably focused on ASA journals, the data we prepared gave us an opportunity to provide an overview of the agricultural sciences literature as part of our continuing series of journal citation studies.

The agricultural sciences today span a broad spectrum of research on virtually all aspects of food production. This includes farm production, soil cultivation and conservation, the growth and harvesting of food crops as well as forage and feed for animals, animal husbandry, and the processing of plant and animal products for consumption.[2]

The rise of agricultural knowledge has been traced back to ancient times, when humankind made the transition from nomadic hunting/gathering tribes to more settled societies supported by domesticated animal herds and cultivated crops. Based on archaeological findings, researchers believe that primitive agriculture developed as early as 9000-7000 BC in the Near East. The Natufians of Palestine used sickles during this period, though it is unclear whether they harvested wild or sown grains. There are also indications that wheat and barley were cultivated as early as 7000 BC in what is now Iran and Iraq.[3]

However, the popular conception that the Middle East was the single center of agricultural development is no longer supported. Domesticated beans, gourds, and water chestnuts seem to have been grown in Thailand approximately 9000 BC, and peppers, avocados, beans, pumpkins, and gourds also were domesticated in the Americas by 7000-5000 BC.[3]

Justus von Liebig and the Growth of Scientific Agriculture

Agricultural knowledge remained an oral tradition, with information transmitted verbally from farmer to farmer, until the turn of the nineteenth century. Agricultural science did not gain a place in academia until the first agricultural academies were established in Hungary in 1796 and Germany in 1818. The earliest effort to put agriculture on an empirical, scientific footing is credited to Justus von Liebig, a German chemist who

Table 1: Core agriculture journals, 1989 *SCI*®, in alphabetic order by publisher, with their years of origin (in parentheses), and 1989 impact factors. (See Table 2 for explanation of impact factor calculations.)

Academic Press, US	
Advances in Agronomy (1949)	1.00
Agricultural Institute of Canada	
Canadian Journal of Soil Science (1957)	0.73
Akademie Verlag, Germany	
Archiv für Acker- und Pflanzenbau und Bodenkunde (1971)	0.24
Almqvist & Wiksell, Sweden	
Swedish Journal of Agricultural Research (1933)	0.29
American Chemical Society	
Journal of Agricultural and Food Chemistry (1953)	1.20
American Society of Agricultural Engineers	
Transactions of the ASAE (1907)	0.37
American Society of Agronomy	
Crop Science Society of America	
Soil Science Society of America	
Agronomy Journal (1907)	0.71
Crop Science (1961)	0.61
Soil Science Society of America Journal (1936)	1.18
American Society for Enology and Viticulture	
American Journal of Enology and Viticulture (1948)	0.66
Blackwell Scientific, UK	
Journal of Soil Science (1949)	0.95
British Society for Research in Agricultural Engineering	
Academic Press, UK	
Journal of Agricultural Engineering Research (1956)	0.23
Butterworth-Heinemann, UK	
Crop Protection (1982)	0.45
Tropical Agriculture (1924)	0.11
CAB	
Pergamon Press, UK	
Outlook on Agriculture (1956)	0.25
Cambridge University Press, UK	
Experimental Agriculture (1933)	0.25
Journal of Agricultural Science (1905)	0.49
Canadian Society of Agricultural Engineering	
Canadian Agricultural Engineering (1959)	0.34
Council of Scientific and Industrial Research Organizations, Australia	
Australian Journal of Agricultural Research (1950)	0.74
Australian Journal of Experimental Agriculture (1961)	0.40
Australian Journal of Soil Research (1963)	0.84
Tropical Grasslands (1967)	0.11
DSIR, New Zealand	
New Zealand Journal of Agricultural Research (1938)	0.43
New Zealand Journal of Crop and Horticultural Science (1973)	0.21
Elsevier Scientific, France	
Apidologie (1970)	0.56
Elsevier Science, The Netherlands	
Agriculture Ecosystems & Environment (1983)	0.27
Agricultural and Forest Meteorology (1964)	0.63
Agricultural Water Management (1976)	0.10
Field Crops Research (1977)	0.63
Geoderma (1967)	0.56
Soil & Tillage Research (1980)	0.53
Elsevier Applied Science, UK	
Agricultural Systems (1976)	0.40
Biological Wastes (1979)	0.21
Biomass (1981)	0.48
Journal of the Science of Food and Agriculture (1950)	0.68
Pesticide Science (1970)	1.02
Entomological Society of America	
Journal of Economic Entomology (1908)	0.74
European Association for Potato Research, The Netherlands	
Potato Research (1958)	0.33
European Weed Research Society, UK	
Weed Research (1961)	0.35
Istituto Sperimentale per la Cerealicoltura, Italy	
Maydica (1956)	0.20
International Bee Research Association, UK	
Bee World (1919)	0.19
JG Press, US	
Biocycle (1960)	0.22
Kluwer, The Netherlands	
Euphytica (1952)	0.39
Plant and Soil (1948)	0.69
Kyushu University, Japan	
Journal of the Faculty of Agriculture, Kyushu University (1923)	0.13
Japan Society for Bioscience, Biotechnology, and Agrochemistry	
Agricultural and Biological Chemistry (1961)	0.86
Japanese Society of Soil Science and Plant Nutrition	
Soil Science and Plant Nutrition (1955)	0.52
Marcel Dekker, US	
Communications in Soil Science and Plant Analysis (1970)	0.47
Journal of Environmental Science and Health Part B—Pesticides, Food Contaminants and Agricultural Wastes (1976)	0.60
Pergamon Press, UK	
Journal of Stored Products Research (1965)	0.28
Soil Biology & Biochemistry (1969)	1.31
Pesticide Science Society of Japan	
Journal of Pesticide Science (1973)	0.54
Potato Association of America	
American Potato Journal (1913)	0.40
Royal Netherlands Society for Agricultural Science	
Netherlands Journal of Agricultural Science (1953)	0.36
Soil and Water Conservation Society, US	
Journal of Soil & Water Conservation (1946)	0.59
Scandinavian Association of Agricultural Scientists	
Royal Swedish Academy of Agriculture and Forestry	
Acta Agriculturae Scandinavica (1945)	0.48
Springer Verlag, US	
Biology and Fertility of Soils (1985)	0.79
Irrigation Science (1978)	0.58
University of California, US	
Hilgardia (1925)	1.06

Verband der Cigarettenindustrie, Germany	
Beiträge zur Tabakforschung International (1961)	0.50
Verbandes Deutscher Landwirtschaftlicher Untersuchungs und Forschungsanstalten	
Sauerlander, Germany	
Agribiological Research: Zeitschrift für Agrarbiologie—Agrikulturchemie—Ökologie (1949)	0.32
Verlag Paul Parey, Germany	
Journal of Agronomy and Crop Science—Zeitschrift für Acker- und Pflanzenbau (1853)	0.16
Plant Breeding—Zeitschrift für Pflanzenzuchtung (1912)	0.71
Weed Science Society of America	
Weed Science (1951)	0.59
Wiley, US	
Soviet Soil Science (1959)	0.08
Williams & Wilkins, US	
Soil Science (1916)	0.65

taught at the Universities of Giessen and Munich in the early and mid-1800s.[2,4]

Liebig is best known for his many contributions to the development of organic chemistry. He systematically extended this knowledge to agriculture and plant physiology, and ultimately put forward the most comprehensive treatment of plant nutrition presented to that time. In 1840, he published what has since been acclaimed as one of the most important books in the history of scientific agriculture, *Organic Chemistry in Its Applications to Agriculture and Physiology*.[5] Among the landmark topics it discussed were the role of carbon in plant nutrition, the source of nitrogen for plant uptake, and the purpose of fertilizers in supplying ammonia and various salts to plants.[4]

Table 2: Core agriculture journals with impact factors of at least 0.50, 1989 *JCR* ® . Impact factors are calculated by dividing 1989 citations to a journal's 1988 and 1987 articles by the number of articles it published in these two years.

Journal	1989 Impact	1988+1987 Articles	1989 Citations
Soil Biol. Biochem.	1.31	283	371
J. Agr. Food Chem.	1.20	548	658
Soil Sci. Soc. Amer. J.	1.18	638	756
Hilgardia	1.06	16	17
Pestic. Sci.	1.02	187	190
Advan. Agron.	1.00	10	10
J. Soil Sci.	.95	125	119
Agr. Biol. Chem. Tokyo	.86	1,225	1,051
Aust. J. Soil Res.	.84	112	94
Biol. Fert. Soils	.79	210	165
Aust. J. Agr. Res.	.74	191	141
J. Econ. Entomol.	.74	594	439
Can. J. Soil Sci.	.73	171	124
Agron. J.	.71	386	275
Plant Breeding	.71	190	134
Plant Soil	.69	674	467
J. Sci. Food Agr.	.68	307	208
Amer. J. Enol. Viticult.	.66	122	81
Soil Sci.	.65	220	143
Agr. Forest Meteorol.	.63	145	91
Field Crop Res.	.63	104	65
Crop Sci.	.61	747	456
J. Environ. Sci. Heal. B	.60	82	49
J. Soil Water Conserv.	.59	196	116
Weed Sci.	.59	300	178
Irrigation Sci.	.58	45	26
Apidologie	.56	61	34
Geoderma	.56	94	53
J. Pestic. Sci.	.54	132	71
Soil Till. Res.	.53	98	52
Soil Sci. Plant Nutr.	.52	122	64
Beitr. Tabakforsch.	.50	14	7

Frederic L. Holmes, University of Western Ontario, London, Canada, summarized Liebig's impact on practical and scientific agriculture:

> Before 1840 it was generally believed that both plant and animal life were dependent on the circulation of an organic, previously living material. Now, whatever opinion individuals held on specific points, they agreed that the nutrient substances of plants were inorganic. That change had transformed the objectives of agriculture, for under the older conception the potential production of foodstuffs would seem to have a fixed limit, whereas in the new view an unbound increase in organic life appeared possible.
>
> Liebig's students and followers provided much of the means for the rigorous scientific study of agriculture that he envisioned, as they began to set up experiment stations in Europe and the United States.[4] (p. 348)

With the momentum built up by Liebig and his followers, a number of agricultural colleges were founded in the US. In 1853, the first state agricultural college was established in New York. The oldest surviving one, however, was established in Michigan in 1857 and is now known as Michigan State University. In 1862, the Morrill Act was passed by Congress and signed by President Abraham Lincoln. This act endowed so-called "land-grant" colleges for the purposes of agricultural research and teaching. In 1887, the Hatch Act provided federal support for cooperative agricultural research between state colleges and the USDA. By 1885, colleges in 16 states had established agricultural experiment stations with the USDA.[2]

At about this time, agronomy came to be recognized as a separate science concentrating specifically on crop and soil management. In 1908, the American Society of Agronomy was established. With more than 12,000 members, it is presently the largest professional society of agronomists in the world. Agronomy today is a multidisciplinary field that draws on, and contributes to, the methods and theories of a wide variety of specialties as they apply to soil and plant management. These include, but are not limited to, biochemistry, biotechnology, botany, chemistry, genetics, microbiology, pathology, physics, and physiology.[6]

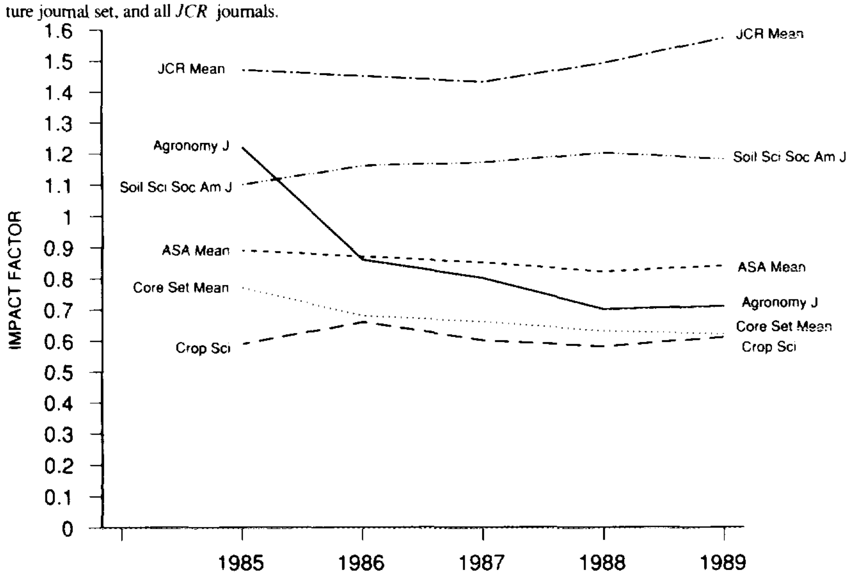
Surveying the Lay of the Land of Agricultural Research

In this essay, we will follow the pattern established in our continuing series of journal citation studies. We will start with a group of 66 agriculture and soil science journals indexed in the 1989 *Science Citation Index* ® (*SCI* ®), and present rankings by impact factors derived from the *SCI Journal Citation Reports* ® (*JCR* ®). Impact factors reflect the average number of citations per published "source item" during a two-year period. Source items include research articles, review articles, and technical notes, but not editorials, news reports, obituaries, or other items that are fully indexed in *SCI*. For simplicity's sake, source items will be referred to as articles. Thus, 1989 impact factors are calculated by dividing 1989 citations to a journal's 1988 and 1987 articles by the total number of articles it published in these two years.

Then, we will treat the 66 core journals as if they composed one large "Macrojournal of Agriculture." This allows us to identify the journals it cited most frequently and those by which it was most cited.

This is followed by a list of the most-cited core journal articles to give a perspective on classic research topics examined by agronomists and soil scientists. In addition, articles in *non*-core journals that were most-cited by

Figure 1: Impact factor trends, 1985-1989 *JCR* ®, for American Society of Agronomy (ASA) journals, core agriculture journal set, and all *JCR* journals.



the core agriculture journals are presented. Another perspective on specialty areas within agricultural research is provided by examining the 1989 research fronts that included the greatest number of core journal articles.

Core Agriculture/Soil Science Journals, 1989 *SCI JCR*

Table 1 presents the 66 agriculture and soil science journals covered in the 1989 *SCI*, arranged by publisher and showing the year each was launched and its 1989 impact factor. The oldest is *Journal of Agronomy and Crop Science—Zeitschrift für Acker- und Pflanzenbau*, which began in 1853 and is published by Verlag Paul Parey, Berlin, Germany. Next in age are *Journal of Agricultural Science*, published by Cambridge University Press, UK (1905); the American Society of Agricultural Engineers' *Transactions* and ASA's *Agronomy Journal*, both of which were launched in 1907; and the *Journal of Economic Entomology* (1908), published by the Entomological Society of America.

The most recently published are *Biology and Fertility of Soils* (1985), Springer Verlag, New York; *Agriculture Ecosystems & Environment* (1983), Elsevier Science, Amsterdam, The Netherlands; *Crop Protection* (1982), Butterworth-Heinemann, Guildford, UK; *Biomass* (1981), Elsevier Applied Science, Barking, UK; and *Soil & Tillage Research* (1980), Elsevier Science.

Of the journals in Table 1, 19 are published in the US, including an English translation of *Soviet Soil Science* published by Wiley, New York; 16 are from the UK, 5 of which are published by Elsevier; 10 are published in The Netherlands (6 by Elsevier); followed by Germany with 5; Australia and Japan with 4 each; Canada, New Zealand, and Sweden with 2 each; and France and Italy with 1 each.

Highest Impact Core Journals

Table 2 lists 32 journals with a 1989 impact factor of at least 0.50 and shows the number of 1989 citations to each journal's 1988 and 1987 articles as well as the number of articles each published in these years. *Soil Biology and Biochemistry*, published by Pergamon, Exeter, UK, has the highest impact factor—1.31. That is, it published 283 source items in 1988 and 1987 and received 371 citations in 1989. The American Chemical Society's *Journal of Agricultural and Food Chemistry* is second with an impact factor of 1.20, followed by *Soil Science Society of America Journal* at 1.18. *Hilgardia*, published by the University of California, Oakland, ranks fourth with an impact of 1.06, followed by Elsevier Applied Science's *Pesticide Science* and Academic Press' *Advances in Agronomy* with virtually identical impacts of 1.02 and 1.00, respectively.

The mean impact factor for the 66 core agriculture journals as a group was 0.62. In comparison, the mean impact for all 4,500 journals covered in the 1989 *JCR* was 1.57.

Of course, we should not make too much of these specific rankings since the difference separating some of these journals amounts to no more than one-hundredth of a point. Although quantitative indicators are useful, one must be careful not to split hairs among journals that differ by only 0.01 or 0.05 points on impact or other factors.

It also is more illuminating to consider trends over several years rather than rankings in a single year. Figure 1 shows a graph prepared for my presentation at the ASA annual meeting. It illustrates impact factor trends during a five-year period from 1985 to 1989—for each ASA journal, for all ASA journals, and for the core set of 66 agriculture journals. It also gives the mean for all 4,500 journals covered in the *JCR*.

In 1985, *Agronomy Journal* had the highest impact of the ASA journals at 1.2, well above the ASA mean of 0.9 and the core set mean of 0.8. But by 1989, its impact had slipped to 0.7, slightly below the ASA mean of 0.8, but still higher than the core set mean of 0.6. The *Soil Science Society of America Journal* slightly improved its impact factor from 1.1 in 1985 to 1.2 in 1989, while *Crop Science* maintained its impact at 0.6 with

Table 3: The 50 journals most cited by the core agriculture journals, 1989 *SCI*®. Asterisks (*) indicate core journals. A=citations from core journals. B=citations from all journals. C=self-citations. D=percent of total citations that are core-journal citations (A/B). E=percent of total citations that are self-citations (self-citing rate, C/B). F=percent of core-journal citations that are self-citations (C/A). G=1989 impact factor. H=1989 immediacy index. I=total 1989 source items.

	A	B	C	D	E	F	G	H	I
*Soil Sci. Soc. Amer. J.	4,833	7,204	1,623	67.1	22.5	33.6	1.19	0.26	330
*Agron. J.	2,913	4,364	689	66.8	15.8	23.7	0.71	0.21	173
*Crop Sci.	2,591	4,709	1,320	55.0	28.0	50.9	0.61	0.16	427
*Soil Sci.	1,740	2,902	212	60.0	7.3	12.2	0.65	0.16	116
*J. Econ. Entomol.	1,663	4,237	1,201	39.2	28.3	72.2	0.74	0.14	326
*Plant Soil	1,628	3,249	550	50.1	16.9	33.8	0.69	0.14	309
*Soil Biol. Biochem.	1,609	2,673	632	60.2	23.6	39.3	1.31	0.27	171
*T. ASAE	1,498	1,986	837	75.4	42.1	55.9	0.37	0.08	277
*Agr. Biol. Chem. Tokyo	1,463	6,416	1,267	22.8	19.7	86.6	0.86	0.32	625
*J. Agr. Food Chem.	1,298	5,999	698	21.6	11.6	53.8	1.20	0.20	340
Plant Physiol.	1,124	20,333	---	5.5	---	---	2.84	0.42	754
*Weed Sci.	1,027	1,625	642	63.2	39.5	62.5	0.59	0.16	116
J. Biol. Chem.	984	183,385	---	0.5	---	---	6.64	0.97	3,292
*J. Soil Sci.	984	1,451	234	67.8	16.1	23.8	0.95	0.27	77
*Aust. J. Agr. Res.	937	1,885	332	49.7	17.6	35.4	0.74	0.30	120
*J. Agr. Sci.	918	2,359	187	38.9	7.9	20.4	0.49	0.06	107
J. Environ. Qual.	803	1,867	---	43.0	---	---	1.20	0.26	94
*J. Sci. Food Agr.	773	2,835	265	27.3	9.3	34.3	0.68	0.19	182
Nature	752	178,265	---	0.4	---	---	18.06	4.21	1,045
Phytopathology	744	7,190	---	10.3	---	---	1.51	0.27	236
Appl. Environ. Microbiol.	688	12,251	---	5.6	---	---	2.43	0.32	584
*Can. J. Soil Sci.	688	971	206	70.9	21.2	29.9	0.73	0.10	90
Science	655	117,063	---	0.6	---	---	18.26	3.61	829
Agronomy	587	707	---	83.0	---	---	N/A	N/A	0
J. Food Sci.	534	5,68	---	9.4	---	---	0.80	0.12	427
*Aust. J. Exp. Agr.	511	726	19	70.4	26.3	37.4	0.40	0.14	104
*Aust. J. Soil Res.	510	658	169	77.5	25.7	33.1	0.84	0.41	63
Water Resour. Res.	477	4,354	---	11.0	---	---	1.73	0.39	236
Environ. Entomol.	466	2,626	---	17.7	---	---	0.73	0.16	186
Theor. Appl. Genet.	463	3,213	---	14.4	---	---	1.62	0.16	263
Biochim. Biophys. Acta	455	65,848	---	0.7	---	---	2.26	0.34	1,899
*Commun. Soil Sci. Plant Anal.	439	730	153	60.1	21.0	34.9	0.47	0.05	134
Ann. Appl. Biol.	436	1,987	---	21.9	---	---	0.49	0.17	104
Can. J. Plant Sci.	436	1,357	---	32.1	---	---	0.44	0.12	162
*Advan. Agron.	434	681	26	63.7	3.8	6.0	1.00	0.00	9
Phytochemistry	417	10,002	---	4.2	---	---	1.10	0.20	808
New Phytol.	416	4,110	---	10.1	---	---	1.46	0.31	200
*Euphytica	409	1,021	193	40.1	18.9	47.2	0.39	0.13	168
J. Anim. Sci.	405	8,348	---	4.9	---	---	1.36	0.30	390
*Agr. Forest Meteorol.	393	736	244	53.4	33.2	62.1	0.63	0.04	102
Physiol. Plant.	378	6,186	---	6.1	---	---	1.76	0.28	273
Can. J. Bot.	363	5,867	---	6.2	---	---	0.81	0.20	418
Ann. Bot.	360	2,722	---	13.2	---	---	0.71	0.17	163
*N. Z. J. Agr. Res.	357	694	139	51.4	20.0	38.9	0.43	0.19	62
*Pestic. Sci.	345	928	128	37.2	13.8	37.1	1.02	0.11	104
Anal. Chem.	344	27,103	---	1.3	---	---	3.64	0.63	584
J. Exp. Bot.	336	3,356	---	10.0	---	---	1.36	0.25	174
Biochem. J.	334	44,524	---	0.8	---	---	3.63	0.58	1,096
Proc. Nat. Acad. Sci. USA	330	180,604	---	0.2	---	---	9.97	1.34	2,090
*Geoderma	328	567	46	57.8	8.1	14.0	0.56	0.05	39

only slight fluctuation during this period. By comparison, the mean impact for the entire core set declined from 0.8 in 1985 to 0.6 in 1989.

The *Macrojournal of Agriculture*

As stated earlier, we treat the 66 core journals as if they comprise a single "Macrojournal of Agriculture," to see what it cites and, conversely, what cites it. In 1989, the core set published 6,608 articles. This amounts to 1.30 percent of the 507,401 articles included in the *JCR* that year. These articles gave out 122,453 citations to 22,153 journals, or 1.46 percent of the 8.4 million citations in the 1989 *JCR* database.

Just four core journals account for 26 percent of the 6,608 articles published by the core in 1989. They are *Agricultural and Biological Chemistry—Tokyo* (625 articles), *Crop Science* (427), *Journal of Agricultural and Food Chemistry* (340), and *Soil Science Society of America Journal* (330). And, 11 journals account for more than 50 percent of all articles published by the core in 1989. This is merely another illustration of the well-known Bradford and Zipf distributions and various other statistical patterns that have been reviewed previously.[7,8]

Which Journals the Core Cited

Table 3 lists the 50 journals most cited by the core, in descending order of total core citations received, shown in column A. It also gives data on total citations received from all journals (column B); the number of times each journal cited itself, or self-citations (C); the respective percentages of core-to-total (D), self-to-total (E), and self-to-core (F) citations; 1989 impact factors (G); 1989 immediacy indexes (H), or the average number of times a journal's 1989 articles were cited in 1989; and the number of source items published in 1989 (I).

These journals received nearly 43,600 citations from the core group in 1989, which represents 35.6 percent of all citations by the core that year. The core citations also amount to about 5 percent of all the citations these 50 journals received in 1989.

Of the 50 journals most cited by the *Macrojournal of Agriculture*, 25 are themselves core journals (indicated by asterisks). The top 10 journals are all core journals, and the first 3 are ASA publications. The *Soil Science Society of America Journal* leads with 4,833 citations from the core, followed by *Agronomy Journal* (2,913 core citations) and *Crop Science* (2,591).

Plant Physiology is the leading *non*-core journal most cited by the *Macrojournal of Agriculture*, with 1,124 core citations in 1989, representing 5.5 percent of the more than 20,000 citations this journal received from all publications in the *JCR* that year. Two leading multidisciplinary journals—*Nature* and *Science*—also are listed, as is the *Proceedings of the National Academy of Sciences of the United States of America* (*PNAS*). In these cases, core citations amount to less than 0.7 percent of total citations each journal received in 1989. This indicates that the core is selectively citing that fraction of the literature relevant to agronomy and soil science published in *Nature*, *Science*, and *PNAS*. These have tended to appear consistently among our lists of journals most cited by various specialties, which reflects each journal's key position in scientific communication across many disciplines. To a lesser extent, the same is true of large journals that are prominent in a particular field, such as chemistry or the life sciences—*Journal of Biological Chemistry*, *Biochemical Journal*, *Analytical Chemistry*, and so on.

Which Journals Cited the *Macrojournal of Agriculture*

Table 4 lists, again in descending order, the 50 journals that most frequently cited the 66 core agriculture journals in 1989. The core group received more than 39,000 citations from these 50 journals, amounting to 53.5 percent of all citations received by the core in 1989. They also represent 16.4 percent of all citations by the 50 journals listed here that year.

Table 4: The 50 journals that most frequently cited the core agriculture journals, 1989 *SCI*®. Asterisks (*) indicate core journals. A=citations to core journals. B=citations to all journals. C=self-citations. D=percent of total citations that are core-journal citations (A/B). E=percent of total citations that are self-citations (self-cited rate, C/B). F=percent of core-journal citations that are self-citations (C/A). G=1989 impact factor. H=1989 immediacy index. I=total 1989 source items.

	A	B	C	D	E	F	G	H	I
*Soil Sci. Soc. Amer. J.	3,539	7,566	1,623	46.8	21.5	45.9	1.19	0.26	330
*Crop Sci.	2,232	5,623	1,320	39.7	23.5	59.1	0.61	0.16	427
*Plant Soil	1,937	6,491	550	29.8	8.5	28.4	0.69	0.14	309
*Agron. J.	1,542	3,259	689	47.3	21.1	44.7	0.71	0.21	173
*J. Econ. Entomol.	1,521	5,466	1,201	27.8	22.0	79.0	0.74	0.14	326
*Soil Biol. Biochem.	1,454	3,882	632	37.5	16.3	43.5	1.31	0.27	171
*Agr. Biol. Chem. Tokyo	1,379	9,394	1,267	14.7	13.5	91.9	0.86	0.32	625
*T. ASAE	1,344	4,049	837	33.2	20.7	62.3	0.37	0.08	277
*J. Agr. Food Chem.	1,194	6,868	698	17.4	10.2	58.5	1.20	0.20	340
*Commun. Soil Sci. Plant Anal.	1,084	2,271	153	47.7	6.7	14.1	0.47	0.05	134
*Biol. Fert. Soils	1,021	2,796	76	36.5	2.7	7.4	0.79	0.13	111
*Can. J. Soil Sci.	960	1,831	206	52.4	11.3	21.5	0.73	0.10	90
*Soil Sci.	960	2,150	212	44.7	9.9	22.1	0.65	0.16	116
*Weed Sci.	929	2,368	642	39.2	27.1	69.1	0.59	0.16	116
*J. Soil Sci.	914	1,923	234	47.5	12.2	25.6	0.95	0.27	77
*Aust. J. Agr. Res.	891	2,780	332	32.1	11.9	37.3	0.74	0.30	120
ACS Symp. Ser.	809	25,203	---	3.2	---	---	0.90	0.17	869
J. Environ. Qual.	750	2,503	---	30.0	---	---	1.20	0.26	94
*Soil Till. Res.	738	1,322	98	55.8	7.4	13.3	0.53	0.13	63
Can. J. Plant Sci.	680	2,682	---	25.4	---	---	0.44	0.12	162
*Aust. J. Soil Res.	672	1,395	169	48.2	12.1	25.1	0.84	0.41	63
Appl. Environ. Microbiol	623	15,482	---	4.0	---	---	2.43	0.32	584
*Field Crop Res.	607	1,321	102	46.0	7.7	16.8	0.63	0.35	69
J. Food Sci.	593	8,658	---	6.8	---	---	0.80	0.12	427
*Euphytica	573	2,847	193	20.1	6.8	33.7	0.39	0.13	168
*Advan. Agron.	555	1,517	26	36.6	1.7	4.7	1.00	0.00	9
*J. Sci. Food Agr.	533	3,500	265	15.2	7.6	49.7	0.68	0.19	182
*J. Agr. Sci.	524	1,900	187	27.6	9.8	35.7	0.49	0.06	107
*Agr. Forest Meteorol.	513	2,581	244	19.9	9.5	47.6	0.63	0.04	102
Hortscience	507	4,602		11.0			0.42	0.07	403
*Pestic. Sci.	497	2,512	128	19.8	5.1	25.8	1.02	0.11	104
Theor. Appl. Genet.	477	6,087	---	7.8	---	---	1.62	0.16	263
*Aust. J. Exp. Agr.	475	1,457	191	32.6	13.1	40.2	0.40	0.14	104
J. Anim. Sci.	454	10,066	---	4.5	---	---	1.36	0.30	390
Environ. Entomol.	436	3,859	---	11.3	---	---	0.73	0.16	186
J. Plant. Nutr.	431	1,661	---	25.9	---	---	0.51	0.10	84
Plant Physiol.	421	18,944	---	2.2	---	---	2.84	0.42	754
Water Resour. Res.	421	6,046	---	7.0	---	---	1.73	0.39	236
Sci. Total Envir.	405	6,433	---	6.3	---	---	0.68	0.18	307
Z. Pflanz Bodenk.	398	1,395	---	28.5	---	---	0.69	0.23	73
J. Amer. Soc. Hort. Sci.	396	4,094	---	9.7	---	---	0.69	0.15	211
Pestic. Biochem. Physiol.	392	2,424	---	16.2	---	---	1.34	0.16	95
*J. Agron. Crop. Sci.	361	1,376	13	26.2	0.9	3.6	0.16	0.01	89
*N. Z. J. Agr. Res.	353	1,071	139	33.0	13.0	39.4	0.43	0.19	62
*Soil Sci. Plant Nutr.	352	979	113	36.0	11.5	32.1	0.53	0.26	66
J. Chem. Ecol.	334	5,246	---	6.4	---	---	1.46	0.26	213
Can. J. Forest Res.	326	5,750	---	5.7	---	---	0.66	0.13	223
J. Dairy Sci.	319	9,325	---	3.4	---	---	1.25	0.18	360
*J. Agr. Eng. Res.	313	1,109	94	28.2	8.4	30.0	0.23	0.04	74
New Phytol.	308	6,057	---	5.1	---	---	1.46	0.31	200

Table 5: The 20 most-cited articles from the core agriculture journals, 1945-1988 ***SCI*** **®**. Articles are listed in alphabetic order by first author. A=1945-1988 citations. B=1989 citations. An asterisk (*) indicates that the paper was the subject of a *Citation Classic* ® commentary. The issue, year, and edition of *CC* ® in which the commentary appeared follow the bibliographic reference. *SCI/SSCI* ® research-front numbers for 1989 also follow the reference.

A	B	Bibliographic Data
1,155	68	**Abbott W S.** A method of computing the effectiveness of an insecticide. *J. Econ. Entomol.* 18:265-7, 1925. 89-0031
534	47	***Bray R H & Kurtz L T.** Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci.* 59:39-45, 1945. (29/87/AB&ES) 89-3100
356	12	**Chang S C & Jackson M L.** Fractionation of soil phosphorus. *Soil Sci.* 84:133-44, 1957. 89-2941
353	13	***Donald C M.** Competition among crop and pasture plants. *Advan. Agron.* 15:1-118, 1963. (23/79/AB&ES) 89-4754
431	28	***Eberhart S A & Russell W A.** Stability parameters for comparing varieties. *Crop Sci.* 6:36-40, 1966. (19/79/AB&ES) 89-3016
583	51	***Fehr W R, Caviness C E, Burmood D T & Pennington J S.** Stage of development descriptions for soybeans, *Glycine max* (L.) Merrill. *Crop Sci.* 11:929-31, 1971. (12/82/AB&ES) 89-1514
528	32	**Finlay K W & Wilkinson G N.** The analysis of adaption in a plant-breeding programme. *Aust. J. Agr. Res.* 14:742-54, 1963. 89-3016
461	26	**Hardy R W F, Burns R C & Holsten R D.** Applications of the acetylene-ethylene assay for measurement of nitrogen fixation. *Soil Biol. Biochem.* 5:47-81, 1973.
482	22	***Hodge J E.** Dehydrated foods: chemistry of browning reactions in model systems. *J. Agr. Food Chem.* 1:928-43, 1953. (12/79/AB&ES) 89-0284
698	26	**Hydén S.** A turbidimetric method for the determination of higher polyethylene glycols in biological materials. *Lantbrukshoegsk. Ann.* 22:139-45, 1955. (Superceded title of *Swed. J. Agr. Res.*)
409	12	**Kilmer V J & Alexander L T.** Methods of making mechanical analyses of soils. *Soil Sci.* 68:15-24, 1949.
427	34	**Lindsay W L & Norvell W A.** Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil Sci. Soc. Amer. J.* 42:421-8, 1978.
430	13	**Martin J P.** Use of acid, rose bengal, and streptomycin in the plate method for estimating soil fungi. *Soil Sci.* 69:215-32, 1950.
344	38	***Ponnamperuma F N.** The chemistry of submerged soils. *Advan. Agron.* 24:29-96, 1972. (22/83/AB&ES)
403	21	**Shorey H H & Hale R L.** Mass-rearing of the larvae of nine noctuid species on a simple artificial medium. *J. Econ. Entomol.* 58:522-4, 1965.
589	24	**Swain T & Hillis W E.** The phenolic constituents of *prunus domesticus*. I.—The quantitative analysis of phenolic constituents. *J. Sci. Food Agr.* 10:63-8, 1959. 89-3208
448	20	**Takatsuki A, Kohno K & Tamura G.** Inhibition of biosynthesis of polyisoprenol sugars in chick embryo microsomes by tunicamycin. *Agr. Biol. Chem. Tokyo* 39:2089-91, 1975.
752	52	**Walkley A & Black I A.** An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Sci.* 37:29-38, 1934.
356	30	**Watanabe F S & Olsen S R.** Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. *Soil Sci. Soc. Proc.* 29:677-8, 1965.
502	74	***Zadoks J C, Chang T T & Konzak C F.** A decimal code for the growth stages of cereals. *Weed Res.* 14:415-21, 1974. (41/85/AB&ES) 89-6672

Thirty journals in Table 4 are core journals, as indicated by asterisks. Again, the ASA journals dominate in terms of the number of times they cited the core. Of the top five journals that most frequently cited the *Macrojournal of Agriculture*, three are published by the ASA—*Soil Science Society of America Journal* leads with more than 3,500 citations to the core group in 1989, followed by *Crop Science* (2,232 citations to the core), and *Agronomy Journal* (1,542). *Plant and Soil*, published by Kluwer, Dordrecht, The Netherlands, ranks third with 1,937 citations to the core, and the Entomological Society of America's *Journal of Economic Entomology* is fifth with more than 1,500 citations. (Another ASA journal, the *Journal of Environmental Quality*, is among the top 20 with 750 citations to the core.)

Comparing Tables 3 and 4, 9 journals appear among the top 10 in both lists—the 5

Table 6: Articles published in non-core journals cited at least 25 times by core agriculture journals, 1989 *SCI*®. Articles are listed in alphabetic order by first author. A=1989 citations from core papers. B=total 1945-1988 *SCI* citations. C=1989 *SCI* citations. An asterisk (*) indicates the paper was the subject of a *Citation Classic*® commentary. The issue, year, and edition of *CC*® in which the commentary appeared follow the bibliographic reference. *SCI/SSCI*® research-front numbers for 1989 also follow the reference.

A	B	C	Bibliographic Data
45	24,366	4,826	**Bradford M M.** A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Anal. Biochem.* 72:248-54, 1976. 89-3034
45	17,510	510	**Davis B J.** Disc electrophoresis—II. Method and application to human serum proteins. *Ann. NY Acad. Sci.* 121:404-27, 1964. 89-4581
33	9,741	573	**DuBois M, Gilles K A, Hamilton J K, Rebers P A & Smith F.** Colorimetric method for determination of sugar and related substances. *Anal. Chem.* 28:350-6, 1956.
57	8,985	413	***Duncan D B.** Multiple range and multiple *F* tests. *Biometrics* 11:1-42, 1955. (4/77)
29	930	59	**Hardy R W F, Holsten R D, Jackson E K & Burns R C.** The acetylene-ethylene assay for N_2 fixation: laboratory and field evaluation. *Plant Physiol.* 43:1185-207, 1968.
122	59,759	9,561	**Laemmli U K.** Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature* 227:680-5, 1970. 89-3034
142	187,652	9,435	***Lowry O H, Rosebrough N J, Farr A L & Randall R J.** Protein measurement with the Folin phenol reagent. *J. Biol. Chem.* 193:265-75, 1951. (1/77)
46	5,880	760	***Murashige T & Skoog F.** A revised medium for rapid growth and bioassays with tobacco tissue cultures. *Physiol. Plant.* 15:473-97, 1962. (43/78) 89-4032
59	2,052	158	***Murphy J & Riley J P.** A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta* 27:31-6, 1962. (12/86/AB&ES)
27	787	82	**Phillips J M & Hayman D S.** Improved procedures for clearing roots and staining parasitic and vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection. *Trans. Brit. Mycol. Soc.* 55:158-61, 1970. 89-3375

noted previously as well as *Agricultural and Biological Chemistry—Tokyo*, *Journal of Agricultural and Food Chemistry*, *Soil Biology & Biochemistry*, and *Transactions of the ASAE*.

High Impact Articles in the Agricultural Sciences

Tables 5 and 6 present separate sets of articles that have proven to be of wide interest to agronomists and soil scientists. Table 5 lists the 20 most-cited articles from the core journals, based on the 1945-1988 *SCI* database. Table 6 shows 10 articles published in *non*-core journals that were cited at least 25 times by the core in 1989.

The most-cited core journal article in Table 5 is a 1925 *Journal of Economic Entomology* article describing a method for calculating the effectiveness of an insecticide.[9] Authored by W.S. Abbott, USDA, Washington, DC, it received 1,155 citations in the 1945-1988 *SCI* and was cited 68 times in 1989, indicating continued use of the method described. The paper also appeared in our previously published study of the most-cited articles in the 1955-1986 *SCI*.[10]

Seven papers in Table 5 were the subject of *Citation Classic*® commentaries by the authors. They are indicated by asterisks, and the issue, year, and edition of *Current Contents*® (*CC*®) in which the commentaries appeared follow the reference in parentheses.

As is frequently the case with *Citation Classic* commentaries, the authors offer insights into subjects that range far afield from the specific research problem addressed in their papers. An example is the commentary by John E. Hodge, Cereal Science and Foods Laboratory, USDA, Peoria, Illinois, on his 1953 *Journal of Agricultural and Food Chemistry* paper on the chemistry of browning reactions.[11] He described how a series of chance discoveries led him to write the now classic paper, and observed: "Today's tightly organized research seems to leave little room for serendipity. Then [in the 1950s], research was planned as it progressed; dollar values were not preassessed. Now, plans of work predominate, while chance discoveries suffocate. How bench

Table 7: The 1989 *SCI* ® /*SSCI* ® research fronts that include at least 60 citing documents published in the core agriculture journals. A=number of articles from core agriculture journals citing the core of each front. B=total number of citing documents. C=total number of core documents.

Number	Name	A	B	C
89-0037	Maize protoplasts, plant-regeneration in (*Oryza sativa* L.), stable transformation, anther culture, somatic embryogenesis, and callus formation	64	669	60
89-0614	Growth of winter-wheat roots, leaf emergence, maize phenology, constant temperatures, degree-day model, and dry-matter accumulation	121	267	39
89-0881	Soil microbial biomass, nitrogen mineralization, and transformations of non-symbiotically fixed N_{15}	95	125	11
89-1029	Ammonia volatilization, hydrolysis of urea, atmospheric sampling, wet annular denuder system, nitrogen losses, particulate nitrate, and collection efficiency	112	271	36
89-1087	*Bradyrhizobium japonicum* strains for nodulation, nitrogenase activity, N_2 fixation in Thai soybeans, and narrow-leafed lupin (*Lupinus angustifolius* L.)	120	281	42
89-1364	Acid sulfate soils, molybdate adsorption, reductive dissolution of goethite, solid-solution interface, and aqueous suspensions	83	158	15
89-2184	Conservation tillage, poorly drained Mollic Ochraqualf in northwest Ohio, clay soils, wheel traffic, and potential allelopathic characteristics	69	110	15
89-2679	Poorly drained soil, conservation tillage systems, Mojave desert region, nitrogen losses, particulate nitrate, and collection efficiency	105	117	13
89-3016	Seed yield stability, recurrent selection, international maize trials, oat cultivars, and environmental sensitivity	92	160	15
89-3034	Microtubule cross-linking protein, small synaptic vesicles of rat-brain, and axolinin localization	115	13,994	3
89-3124	Nitrogen mineralization, N_{15} content of soils, and chemolithotrophic nitrification in acid heathland humus	70	83	4
89-3375	Vesicular-arbuscular micorrhizal fungi, lucerne roots in a cellulose-amended soil, and growth of little bluestem (*Schizachyrium scoparium*) (Poaceae)	68	189	19

scientists thrive upon serendipity is illustrated [in this commentary]."[12]

In several of these commentaries, the authors account for the high impact of their classic papers by noting the multidisciplinary nature of agronomy and soil science. For example, F.N. Ponnamperuma, International Rice Research Institute, Los Baños, Philippines, stated that his classic 1972 *Advances in Agronomy* review article on the chemistry of submerged soils involved identifying and reviewing research in: biochemistry; electrochemistry; physical, inorganic, and organic chemistry; thermodynamics; and bacteriology.[13,14]

This point is reinforced by the list of papers in non-core journals most cited by the *Macrojournal of Agriculture* shown in Table 6. They are virtually a compendium of methods that are basic to all life and physical sciences research. James Murphy and John P. Riley, University of Liverpool, UK, noted that their 1962 *Analytica Chimica Acta* paper on determination of phosphate in natural waters has found applications not only in oceanography and water research, but also biochemistry, botany, clinical medicine, geochemistry, metallurgy, zoology, and many other fields.[15,16]

Other papers listed include the supercited classic by Oliver H. Lowry and colleagues, Washington University School of Medicine, St. Louis, Missouri, which has been cited more than 200,000 times since it was published in the *Journal of Biological Chemistry* in 1951.[17,18] In an earlier journal citation study of botany, Brent Heath, York University, North York, Canada, explained that the Lowry method is used by plant scientists to measure plant protein content in order to define a standard against which other plant constituents may be measured—enzyme activity per milligram of protein, for example.[19,20]

Current Research Fronts in the Agricultural Sciences

Table 7 presents 12 research fronts for 1989 that included at least 60 citing articles published in the core agriculture journals that year. The method used to identify and map research fronts has been described in detail previously.[21,22] Briefly explained, the method takes the reference list of a paper and pairs each of the citations with one another. Our computer then searches for other papers that co-cite the same pairs of papers, thereby creating a cluster of research linked by co-citation. The cited papers constitute the core of the cluster while the citing papers make up the current research front. The names of these research fronts are automatically derived from the word pairs and phrases in the titles of the citing papers, much as we do with *KeyWords Plus* SM.[23,24]

The most active agriculture research front in Table 7, in terms of the number of citing articles from core journals, is entitled "Growth of winter-wheat roots, leaf emergence, maize phenology, constant temperature, degree-day model, and dry-matter accumulation" (#89-0614). It includes 121 citing papers from the *Macrojournal of Agriculture*, which represent 45.3 percent of all 267 citing papers in this research front. These papers cited 39 core documents. Next is research front #89-1087, "*Bradyrhizobium japonicum* strains for nodulation, nitrogenase activity, N_2 fixation in Thai soybeans, and narrow-leafed lupin (*Lupinus angustifolius* L.)," with 120 citing articles from the *Macrojournal of Agriculture*.

The research front in which core agriculture articles are most dominant, in terms of their proportionate share of total citing articles, is #89-2679, "Poorly drained soil, conservation tillage systems, Mojave Desert region, nitrogen losses, particulate nitrate, and collection efficiency." Of the 117 citing papers in it, 105 (89.7 percent) were published in core agriculture journals in 1989. Next is #89-3124, "Nitrogen mineralization, N_{15} content of soils, and chemolithotrophic nitrification in acid heartland humus," with 84.3 percent of its 83 citing articles having appeared in the *Macrojournal of Agriculture*.

Conclusion

As is customary in our series of journal citation studies, we conclude by identifying a small number of key publications that appear prominently among the various citation rankings discussed here. Of the 66 core agriculture journals included in this study, 9 ranked among the top 15 in terms of impact, the number citations received by the core, and the number of citations to the core. They are *Agricultural and Biological Chemistry—Tokyo*, *Agronomy Journal*, *Australian Journal of Agricultural Research*, *Journal of Agricultural and Food Chemistry*, *Journal of Economic Entomology*, *Journal of Soil Science*, *Plant and Soil*, *Soil Biology & Biochemistry*, and *Soil Science Society of America Journal*.

In addition, 2 journals ranked among the top 15 in terms of impact and citations to the core, but not citations from the core. They are *Biology and Fertility of Soils* and *Canadian Journal of Soil Science*.

Of course, as in most specialties, agronomists and soil scientists also rely on large multidisciplinary journals, such as *Nature*, *Science*, and *PNAS*, to communicate and learn of important research in their specialties. As noted earlier, other more specialized journals covering broad fields that are relevant to the agricultural sciences, such as biochemistry, are also important.

* * * * *

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