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Current Comments

Journal Citation Studies. 33. Botany Journals, Part 2: Growth of Botanical Literature and Highly-Cited Items

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In part 1 of this study we examined 69 core journals in botany to see what they cite and what cites them.[1] The data showed that botanists cite research published in almost 20,000 journals covering various basic and applied science fields not directly related to botany. At the same time, botanical research is cited by fewer journals (about 900), and in areas more closely related to botany—horticulture, agronomy, and ecology, for example. The data on which the study was based were taken from the 1978 *Science Citation Index® (SCI®) Journal Citation Reports® (JCR™)*.

This second part of our study is based on information taken from the *entire SCI* for the period from 1968 to 1977. We have examined growth and publication patterns of botanical literature for a decade. We've tabulated the number of articles published and the number of references included in a typical botany article. In Table 1, we've included only those core botany journals for which data were available over a four-year period, or longer. Therefore, of the 69 core journals examined in part 1 of this study, only 61 are included in part 2. We have excluded *Advances in Agronomy, Australian Journal of Plant Physiology, Bulletin of the Torrey Botanical Club, Environmental and Experimental Botany, Phytopathologische Zeitschrift, Soviet Plant Physiology, Taxon*, and *Vegetatio*.

For the 61 journals studied, the number of articles published increased from 5,072 in 1968 to 7,684 in 1977 (Table 1). This is an overall increase of 51%, or an annual growth rate of about 4.7%. Over the same period, the *SCI* data base increased from 311,959 items in 1968 to 465,067 in 1977. Thus, the *SCI* grew at an annual average rate of 4.5%. If we assume the *SCI* data base roughly represents the scientific literature as a whole, we can say that botanical literature kept pace with the annual growth rate of scientific publications in general. This is in contrast to the biochemical literature, which grew at a rate of 5.3%.[2]

The individual journals that published the greatest number of articles in 1977 are *Plant Physiology* (1,170), *Phytochemistry* (616), and the *Journal of Phycology* (522). The *Journal of Phycology* shows the largest average annual growth rate between 1968-77 (20.9%), but this is largely due to a jump in source items published in 1976 (200) and 1977 (522). Between 1968 and 1976, the average annual growth rate for the *Journal of Phycology* was only 9.7%. *Zeitschrift für Pflanzenphysiologie* shows an annual average increase of 13.4% from 1968-77, and *Annals of Botany* 10.2%.

Over the same time period, *Phytopathology decreased* the number of articles it published by an average annual rate of 9.4%. The *American Journal of Botany* reduced its output by an average of 9.0% per year. *Dansk Botansk Arkiv* shows the greatest average annual decrease (17.0%), but it didn't publish more than 13 articles in any given year from 1968-77.

Some people may misinterpret the decline in total source items published per year as an indication that a journal is "dying." Remember that source items refer to more than research articles—editorials, abstracts, letters, and other communications are all counted as source items. For example, *Phytopathology* published 913 source items in 1969 (Table 1), of which nearly 600 were abstracts of papers read at various regional meetings of the American Phytopathological Society. In 1975, the same journal published 374 source items, none of which were abstracts. In fact, the Society didn't publish abstracts in its journal from 1974-79. During that time the Society published the abstracts in its proceedings and newsletters. Thus, declines in published source items may ac-

Table 1: Annual total of source items published by each core botany journal, 1968-77.

	Publication Year										
JOURNAL	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**Total**
Acta Biol. Cracov. Ser. Bot.	19	5	15	14	19	13	15	8	12	15	135
Acta Bot. Neer.	80	77	113	75	88	129	77	76	66	60	841
Agri. Hort. Genet. Landskrona	14	5	6	6	2	3	7	4	7	1	55
Amer. J. Bot.	363	153	357	351	332	129	434	135	158	155	2567
Angew. Bot.	—	—	—	—	—	—	30	25	24	28	107
Ann. A. Plant.	29	27	25	30	28	24	39	27	52	55	336
Ann. Bot.	71	82	105	115	102	117	133	136	155	171	1187
Ann. Mo. Bot. Gard.	32	36	26	16	31	29	58	64	50	46	388
Annu. Rev. Phytopathol.	19	19	19	24	20	22	22	21	21	22	209
Annu. Rev. Plant Physiol.	22	25	23	22	17	21	19	20	22	21	212
Aust. J. Bot.	37	42	27	24	25	22	50	62	45	46	380
Ber. Deut. Bot. Ges.	82	69	78	58	73	51	61	26	75	48	621
Biochem. Physiol. Pflanz.	47	51	58	62	68	74	122	131	136	66	815
Biol. Plant.	59	60	58	48	69	76	81	94	69	76	690
Bot. Bull. Acad. Sinica	16	16	14	9	12	20	16	20	20	18	161
Bot. Gaz.	55	44	49	52	62	50	54	58	56	70	550
Bot. J. Lin. Soc.	32	26	21	38	23	40	45	33	43	42	343
Bot. Mag. — Tokyo	73	58	52	49	34	33	33	42	34	37	445
Bot. Notis.	41	63	39	42	58	29	50	42	36	76	476
Bot. Rev.	10	12	9	11	11	12	7	12	10	11	105
Bot. Tidsskr.	19	17	8	14	13	24	20	19	13	18	165
Brittonia	41	36	33	35	85	34	43	36	46	40	429
Bryologist	48	53	55	66	67	81	72	70	70	98	680
Can. J. Bot.	221	306	339	314	334	325	345	336	315	351	3186
Can. J. Plant Sci.	124	139	142	106	178	177	164	205	200	206	1641
Commun. Soil Sci. Plant Anal.	—	—	—	—	—	—	58	59	57	79	253
Dan. Bot. Ark.	11	13	1	1	3	1	3	3	2	2	40
Econ. Bot.	47	43	52	42	42	33	30	36	41	48	414
Euphytica	106	49	70	73	64	81	94	110	91	101	839
Flora	—	—	—	31	32	37	33	27	39	47	246
Isr. J. Bot.	42	23	49	56	38	59	21	52	52	49	441
J. Arnold Arboretum	24	33	22	28	26	21	29	24	18	26	251
J. Exp. Bot.	81	79	108	100	110	133	120	94	137	140	1102

J. Brit. Grassland Soc.	48	57	47	55	44	47	55	59	38	40	490
J. Bryol.	—	—	—	—	22	32	20	18	33	23	148
J. Phycol.	95	64	127	137	61	171	181	184	200	522	1742
Lloydia — J. Nat. Prod.	88	99	103	35	98	110	46	128	131	124	962
New Phytol.	78	104	109	112	121	138	115	117	135	151	1180
Oecol. Plant.	—	33	54	70	72	67	101	125	136	150	808
Photosynthetica	29	42	37	56	56	53	50	59	64	46	492
Physiol. Plant Pathol.	—	—	—	51	44	55	49	94	69	64	426
Physiol. Plant.	147	152	140	185	138	174	199	196	200	183	1714
Physiol. Veget.	31	27	48	57	75	53	50	78	75	74	568
Phytochemistry	344	427	446	674	781	659	629	746	627	616	5949
Phyton — Ann. Rei Bot. Austria	16	14	19	—	11	15	33	14	16	9	147
Phytopathology	744	913	929	709	857	580	475	374	317	307	6205
Plant Cell Physiol.	98	102	127	141	132	137	140	154	154	184	1369
Plant Dis. Rep.	—	—	—	401	381	361	383	332	359	330	2547
Plant Pathol.	58	42	63	50	50	50	45	66	57	50	531
Plant Physiol.	598	527	609	629	704	741	782	895	929	1170	7584
Plant Sci. Lett.	—	—	—	—	—	—	120	125	118	162	525
Plant Soil	99	99	136	194	146	147	148	125	141	214	1449
Plant Syst. Evol.	32	77	46	39	28	56	7	34	49	52	420
Planta	213	233	210	213	226	241	221	204	244	240	2245
Planta Med.	76	54	77	89	108	110	119	152	131	142	1058
Qual. Plant.	57	76	14	24	28	39	23	25	43	32	361
Rev. Palaeobot. Palynol.	35	14	18	22	33	22	39	32	37	36	288
Weed Res.	43	50	48	48	51	54	61	63	59	60	537
Weed Sci.	150	143	173	165	132	146	132	115	131	105	1392
Z. Pflanzenphysiol.	84	84	103	119	135	124	180	147	211	261	1448
Z. Pflanzenzucht.	44	48	47	54	52	56	93	65	73	68	600
Total	5072	5142	5703	6241	6652	6338	6881	6833	6949	7684	
Average	95.7	95.2	105.6	109.5	114.7	109.3	112.8	112.0	113.9	126.0	
SCI data base (in thousands)	312	345	355	365	381	400	401	429	441	465	

tually be a sign of journal "health"—it may be publishing as many research articles but fewer short communications.

Table 2 shows the average number of references per article published in the core journals from 1968-77. The figures are calculated by dividing the references contained in all issues of a journal during a single year (R) by the source items it published that year (S). Most of the 61 journals in Table 2 (49) averaged between 10-29 references. Six have R/S values less than ten.

Three journals in Table 2 published papers that, on average, included 100 or more references throughout the ten year period: *Annual Review of Phytopathology* (103.6), *Annual Review of Plant Physiology* (175.2), and *Botanical Review* (178.8). Not surprisingly, all three are review journals. Three more journals show average R/S values between 30-49: *Botanical Journal of the Linnean Society* (30.4), *Dansk Botansk Arkiv* (48.9), and *Journal of the Arnold Arboretum* (40.3). However, none of these published more than 45 articles in a given year (Table 1), and *Dansk Botansk Arkiv* only published between one and 13 articles from 1968-77. As it turns out, these three journals publish a large number of review articles. This is not apparent from their titles.

For each year during 1968-77, the average botany article contained at least 17% more references than the average *SCI* item. While the difference is not insignificant, part of it may be due to the

Table 2: Average number of references per source item (R/S) for the core botany journals and all *SCI*® journals, 1968-77.

Publication Year

JOURNAL	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	Average 1968-77
Acta Biol. Cracov. Ser. Bot.	20.7	18.4	15.4	34.0	20.2	36.0	37.1	32.5	44.8	21.6	27.6
Acta Bot. Neer.	11.1	16.6	13.1	15.3	11.8	9.1	15.9	10.8	13.3	12.4	12.7
Agri. Hort. Genet. Landskrona	7.7	12.4	22.2	5.5	370.0	14.0	5.8	33.8	4.6	115.0	26.2
Amer. J. Bot.	9.1	21.8	9.1	6.5	8.2	23.1	6.7	23.4	24.0	23.0	12.2
Angew. Bot.	—	—	—	—	—	—	23.6	18.4	21.0	19.7	20.8
Ann. A. Plant.	12.3	21.1	18.2	14.5	18.2	14.0	11.2	22.8	16.5	21.5	17.1
Ann. Bot.	19.2	18.4	15.8	16.4	15.3	18.3	17.8	17.6	19.0	19.8	17.9
Ann. Mo. Bot. Gard.	5.4	14.3	10.2	16.3	27.4	22.3	61.6	26.3	17.2	24.8	25.7
Annu. Rev. Phytopathol.	101.1	117.4	103.2	90.0	104.6	112.3	114.0	77.6	117.5	100.3	103.6
Annu. Rev. Plant Physiol.	170.2	176.2	155.9	140.3	154.2	193.2	232.3	188.0	187.9	158.5	175.2
Aust. J. Bot.	23.7	20.6	22.0	18.4	26.6	20.5	28.4	20.9	26.4	24.6	23.5
Ber. Deut. Bot. Ges.	17.0	20.3	19.0	18.1	19.7	24.9	20.7	58.7	26.9	26.1	22.6
Biochem. Physiol. Pflanz.	25.4	23.3	20.6	17.1	17.5	17.7	20.5	21.6	19.8	20.4	20.3
Biol. Plant.	17.2	15.3	16.0	15.8	16.4	13.7	14.2	14.7	13.8	15.8	15.2
Bot. Bull. Acad. Sinica	15.4	11.6	15.2	12.2	22.9	17.6	14.9	15.0	14.1	18.0	15.7
Bot. Gaz.	17.6	14.9	19.6	18.9	18.7	16.4	18.6	19.2	21.8	21.5	18.9
Bot. J. Lin. Soc.	23.6	28.3	24.0	13.5	23.8	50.1	26.8	31.6	40.8	32.3	30.4
Bot. Mag. — Tokyo	16.3	15.5	13.0	15.8	14.2	12.8	17.1	13.7	14.6	12.5	14.7
Bot. Notis.	17.6	10.9	21.1	18.4	17.9	29.4	15.7	23.1	16.9	16.8	17.9
Bot. Rev.	233.3	137.5	189.1	219.2	194.8	110.3	280.0	139.8	186.8	155.3	178.8
Bot. Tidsskr.	28.4	28.7	26.3	24.1	19.9	19.6	33.7	24.6	31.3	36.9	27.4
Brittonia	13.3	16.3	14.8	15.4	5.7	21.1	12.7	14.9	11.8	21.5	13.6
Bryologist	8.4	17.1	16.2	12.9	14.3	12.0	15.3	14.1	12.2	12.5	13.5
Can. J. Bot.	18.2	17.0	17.8	19.2	19.9	19.6	20.2	21.1	24.2	21.2	19.9
Can. J. Plant Sci.	8.0	8.9	8.2	7.6	9.0	9.9	9.3	9.8	9.3	11.2	9.3
Commun. Soil Sci. Plant Anal.	—	—	—	—	—	—	10.3	14.7	15.2	11.3	12.7
Dan. Bot. Ark.	18.4	6.6	28.0	130.0	98.7	175.0	64.3	91.7	135.0	150.0	48.9
Econ. Bot.	18.0	22.7	21.9	19.6	35.4	27.8	24.3	20.9	24.5	22.4	23.5
Euphytica	11.4	12.3	13.4	14.8	16.5	14.8	13.3	13.6	15.1	15.4	14.0
Flora	—	—	—	29.3	30.5	27.8	26.2	27.1	23.1	23.5	26.5
Isr. J. Bot.	9.5	12.2	12.0	7.6	7.1	6.5	20.7	6.2	6.8	6.1	8.5
J. Arnold Arboretum	20.8	30.2	41.8	64.2	26.9	29.8	56.4	41.7	59.4	33.6	40.3
J. Exp. Bot.	18.7	20.8	19.1	19.8	19.0	18.4	19.9	20.3	20.0	20.2	19.6
J. Brit. Grassland Soc.	11.0	12.7	14.2	7.7	9.6	11.3	8.0	14.9	12.3	12.5	11.4
J. Bryol.	—	—	—	—	9.5	11.3	33.9	47.1	8.3	14.1	18.2
J. Phycol.	11.5	19.8	10.4	8.9	22.5	10.5	9.3	9.5	10.0	3.2	8.7
Lloydia—J. Nat. Prod.	27.3	32.5	31.1	52.4	10.9	13.0	39.9	15.1	14.8	15.5	21.6
New Phytol.	23.1	26.3	17.3	20.2	21.1	21.1	24.5	21.3	22.1	23.1	22.0
Oecol. Plant.	—	30.5	21.9	17.3	21.2	25.7	22.7	23.6	25.4	25.4	23.7
Photosynthetica	18.6	18.9	20.9	15.5	18.2	21.5	31.7	24.2	19.4	28.0	21.7
Physiol. Plant Pathol.	—	—	—	22.7	18.5	19.3	23.1	21.7	21.5	21.2	21.2
Physiol. Plant.	20.8	18.5	18.5	20.0	20.8	19.6	20.2	19.3	19.9	21.5	19.9
Physiol. Veget.	32.8	30.8	26.5	16.4	20.7	25.8	23.8	21.2	25.5	25.2	23.9
Phytochemistry	17.1	15.6	16.4	13.9	14.4	15.6	14.9	14.8	16.1	15.7	15.3
Phyton—Ann. Rei Bot. Austria	12.6	28.2	19.1	—	14.0	25.4	22.1	23.7	22.3	21.1	21.1

Phytopathology	7.2	7.2	6.4	6.6	5.0	8.9	11.7	14.2	14.6	15.9	8.4
Plant Cell Physiol.	14.7	16.1	15.7	13.8	15.7	16.9	16.8	16.1	18.7	16.3	16.1
Plant Dis. Rep.	—	—	—	6.4	6.6	7.2	7.0	8.0	7.7	9.0	7.4
Plant Pathol.	6.1	5.8	5.3	7.3	6.0	5.1	5.5	6.0	5.1	6.3	5.8
Plant Physiol.	11.6	11.2	11.5	11.7	10.9	10.9	10.9	9.9	8.6	8.2	10.3
Planta	20.0	18.1	17.9	17.9	18.6	18.3	19.8	18.7	20.5	21.5	19.2
Plant Soil	15.6	15.1	18.6	17.1	13.2	13.5	13.9	18.4	14.3	15.2	15.5
Plant Syst. Evol.	22.8	18.8	19.4	23.1	23.0	19.4	22.6	20.0	27.2	18.3	21.0
Plant Sci. Lett.	—	—	—	—	—	—	15.9	16.1	17.2	16.1	16.3
Planta Med.	17.8	13.8	17.1	13.2	16.2	15.5	13.3	14.5	12.4	12.1	14.3
Qual. Plant.	16.1	20.1	21.5	31.0	17.5	22.1	23.9	28.3	22.7	21.4	21.5
Rev. Palaeobot. Palynol.	45.6	18.5	22.3	17.0	21.6	32.8	24.4	30.2	32.0	35.8	29.5
Weed Res.	24.5	14.3	14.0	10.2	11.1	12.2	13.6	12.8	17.0	15.6	14.4
Weed Sci.	10.9	11.1	13.5	12.1	12.0	12.0	13.1	11.7	13.9	14.4	12.4
Z. Pflanzenphysiol.	21.2	19.4	20.6	18.5	17.9	19.4	19.8	20.2	19.2	18.6	19.3
Z. Pflanzenzucht.	22.7	24.6	24.7	21.8	20.8	20.9	19.5	19.7	15.8	16.5	20.2
Avg. Botany Jnl.	15.9	16.7	15.4	14.8	14.5	16.2	16.9	17.0	17.4	16.2	
Avg. *SCI* Jnl.	12.0	11.6	12.6	12.1	12.4	12.6	13.1	13.3	13.7	13.5	

inclusion in the *SCI* data base of letters, abstracts, and short communications. Thus, the *SCI* contains items that often lack any references at all, and this "dilutes" the *SCI*'s R/S values in comparison to those for botany articles. By contrast, we found that biochemical articles contained 70% more references than the average *SCI* item.[2]

The average R/S values for articles published in core botany journals remained steady over the ten year period, increasing only 1.9% from 15.9 in 1968 to 16.2 in 1977. The *SCI*, on the other hand, increased its R/S values by 12.5% from 1968-77. However, average botany article R/S values fluctuate from year to year, with a low of 14.5 in 1972 to a high of 17.4 in 1976. Moreover, the number of core botany journals increased from 53 in 1968 to 61 in 1977, and the addition of new journals may have contributed to the fluctuation in total R/S values.

To get a clearer idea of how the botany literature grew in terms of source items published and R/S values from 1968-77, we can exclude from consideration review journals and journals that began publishing after 1968. This leaves us with 49 core botany journals that published *consecutively* from 1968-77. Information on them is listed in Table 3. Table 3 shows that the number of source items published in these 49 core journals increased from 5,005 in 1968 to 6,738 in 1977. This amounts to an overall growth of 34.6%, or an annual average of 3.3%. Also, the average article's R/S value increased from 14.4 in 1968 to 15.3 in 1977, representing an overall increase of 6.2%. Again, these figures show that while the botany literature grew steadily over the years, the average botany article didn't significantly increase the number of its references from 1968 to 1977. This is in contrast to the average biochemical article, which increased its number of references 10.4% over the same time.[2]

In part one of this study,[1] plant biologist Jacob Levitt, Carnegie Institution of Washington, Stanford, California, estimated that as much as 75% of the botany literature describes basic research in plant physiology. Obviously, we can't definitively confirm his suggestion. Such an effort would require an article-by-article survey of the entire botany literature, which in 1978 alone amounted to more than 11,000 articles.[1] However, we can look at a selected sample of botany articles to see if plant physiology dominates botanical research.

Table 4 lists the most-cited botany article from each core journal that had more than 30 citations from 1961-78. Of

Table 3: Total number of references, total number of source items, and average number of references per source item (R/S) for the core botany journals publishing consecutively since 1968, and average number of references per source item (R/S) for all *SCI* journals.

	YEAR OF PUBLICATION									
	1968	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**
Total References for 49 Core Botany Journals	72,329	74,752	79,036	79,247	83,439	87,766	95,750	96,100	99,790	103,328
Total Source Items for 49 Core Botany Journals	5,005	5,039	5,579	5,631	6,042	5,716	6,006	5,961	6,093	6,738
Average R/S for 49 Core Botany Journals	14.4	14.8	14.2	14.1	13.8	15.3	15.9	16.1	16.4	15.3
Average R/S for All *SCI* Journals	12.0	11.6	11.6	12.1	12.4	12.6	13.1	13.3	13.7	13.5

the 42 articles listed, 28 concentrate on plant physiology—growth conditions, function, and biochemical processes of plants or algae. Thus, the data presented in Table 4 roughly confirm Levitt's estimate. The remaining 14 articles describe various methods, and research in the anatomy, ecology, and evolution of plant systems.

One of the most-cited papers in Table 4 is from the *Canadian Journal of Botany*. In the first part of this study,[1] I explained that we dropped this journal from coverage in *Current Contents®/ Life Sciences (CC®/LS)* because its impact was not impressive. However, we reinstated it after deciding there were many other journals in other fields with lower impact, which we still cover. We now have more reasons to continue to cover the *Canadian Journal of Botany* in *CC/LS*, since it publishes highly-cited research despite its relatively low impact. In fact, it published seven papers that were cited more than 30 times from 1961-78.

As a more up-to-date selection, in Table 5 we've compiled a list of 46 published items cited 20 times or more by the core in 1978. Thirty-one items are articles and 15 are books. The articles illustrate the importance of noncore journals in the botany literature. Sixteen articles were published in noncore journals while 15 appeared in core journals.

About 15 items on the list have appeared on our earlier lists of most-cited papers or books, so there is no need to elaborate on them. Once again, they reflect that the plant sciences are another aspect of life science. These papers are published in journals like *Biochemical Journal*, *Journal of Biological Chemistry*, and *Experimental Cell Research*. The general science journals—*Nature*, *Science*, and *Proceedings of the National Academy of Sciences US*—published one paper each in Table 5.

The most-cited item in Table 5 is a paper describing what is often called the Lowry method for protein measurement. As I've reported many times,[3] Lowry's paper is an anomaly—the most-cited item in *all* the scientific literature. Brent Heath, York University, Ontario, Canada, notes that botanists measure plant protein content by Lowry's method in order to define a standard against which other plant constituents are measured—enzyme activity per milligram of protein, for example.[4]

Thirty years after publication, the water culture method of growing plants without soil described by Hoagland and Arnon is still highly-cited. There are

Table 4: Single most-cited paper from each botany core journal having more than 30 citations from 1961-78, in *SCI*®.

Total Citations 1961-1978		Bibliographical Data	
50	Engelsma G & Meijer G.	The influence of light of different spectral regions on the synthesis of phenolic compounds in gherkin seedlings in relation to photomorphogenesis. 1. Biosynthesis of phenolic compounds.	*Acta Bot. Neer.* 14:54-72, 1965.
196	Donald C M.	Competition among crop and pasture plants.	*Adv. Agron.* 15:1-118, 1963.
415	Kratz W A & Myers J.	Nutrition and growth of several blue-green algae.	*Amer. J. Bot.* 42:282-7, 1955.
135	Marchant R & Robards A W.	Membrane systems associated with the plasmalemma of plant cells.	*Ann. Bot.* 32:457-79, 1968.
250	Bracker C E.	Ultrastructure of fungi.	*Annu. Rev. Phytopathol.* 5:343-74, 1967.
320	Beevers L & Hageman R H.	Nitrate reduction in higher plants.	*Annu. Rev. Plant Physiol.* 20:495-522, 1969.
43	Hatch M D, Kagawa T & Craig S.	Subdivision of C_4-pathway species based on differing C_4 acid decarboxylating systems and ultrastructural features.	*Aust. J. Plant Physiol.* 2:111-28, 1975.
65	Melchers G & Labib G.	Die Bedeutung haploider höherer Pflanzen für Pflanzenphysiologie und Pflanzenzüchtung. *(The significance of* haploid higher plants for plant physiology and plant breeding.)	*Ber. Deut. Bot. Ges.* 83:129-50, 1970.
35	Jeffrey S W & Humphrey G F.	New spectrophotometric equations for determining chlorophylls a, b, c_1 and c_2 in higher plants, algae and natural phytoplankton.	*Biochem. Physiol. Pflanz.* 167:191-4, 1975.
108	Borthwick H A, Hendricks S B, Toole E H & Toole V K.	Action of light on lettuce-seed germination.	*Bot. Gaz.* 115:205-25, 1954.
138	Neales T F & Incoll L D.	The control of leaf photosynthesis rate by the level of assimilate concentration in the leaf: a review of the hypothesis.	*Bot. Rev.* 34:107-25, 1968.
51	Crum H A, Steere W C & Anderson L E.	A new list of mosses of North America north of Mexico.	*Bryologist* 76:85-130, 1973.
246	Smillie R M & Krotkov G.	The estimation of nucleic acids in some algae and higher plants.	*Can. J. Bot.* 38:31-49, 1960.
40	Chen C H & Bushuk W.	Nature of proteins in triticale and its parental species. 1. Solubility characteristics and amino acid composition of endosperm protein.	*Can. J. Plant Sci.* 50:9-14, 1970.
73	Wittwer S H & Bukovac M J.	The effects of gibberellin on economic crops.	*Econ. Bot.* 12:213-55, 1958.
75	Donald C M.	The breeding of crop ideotypes.	*Euphytica* 17:385-403, 1968.

65	Ruppel H G.	Untersuchungen über die Zusammensetzung von *Chlorella* bei Synchronisation im Licht-Dunkel-Wechsel. (Investigations on the composition of chlorella during synchronization in light exchange.)	*Flora* 152:113-38, 1962.
32	Drury W H & Nisbet I C T.	Succession.	*J. Arnold Arboretum* 54:331-68, 1973.
600	Tilley J M A & Terry R A.	A two-stage technique for the *in vitro* digestion of forage crops.	*J. Brit. Grassland Soc.* 18:104-10, 1963.
114	Henshaw G G, Jha K K, Mehta A R, Shakeshaft D J & Street H E.	Studies on the growth in culture of plant cells. 1. Growth patterns in batch propagated suspension cultures.	*J. Exp. Bot.* 17:362-77, 1966.
87	Allen M M.	Simple conditions for growth of unicellular blue-green algae on plates.	*J. Phycol.* 4:1-4, 1968.
50	Cordell G A.	Biosynthesis of indole alkaloids.	*Lloydia— J. Nat. Prod.* 37:219-98, 1974.
161	Weatherley P E.	Studies in the water relations of the cotton plant. 1. The field measurement of water deficits in leaves.	*New Phytol.* 49:81-97, 1950.
59	Paine R T.	Intertidal community structure.	*Oecologia Plant.* 15:93-120, 1974.
49	Heath M C & Heath I B.	Ultrastructure of an immune and a susceptible reaction of cowpea leaves to rust infection.	*Physiol. Plant Pathol.* 1:277-87, 1971.
1432	Murashige T & Skoog F.	A revised medium for rapid growth and bio-assay with tobacco tissues cultures.	*Physiol. Plant.* 15:473-97, 1962.
68	Petit A, Delhaye S, Tempe J & Morel M G.	Recherches sur les guanidines des tissus de crown gall. (Studies on guanidines of crown-gall tumors.)	*Physiol. Veget.* 8:205-13, 1970.
368	Loomis W D & Battaile J.	Plant phenolic compounds and the isolation of plant enzymes.	*Phytochemistry* 5:423-38, 1966.
138	Clemons G P & Sisler H D.	Formation of a fungitoxic derivative from Benlate.	*Phytopathology* 59:705-6, 1969.
148	Farkas G L & Kraly Z.	Role of phenolic compounds in the physiology of plant disease and disease resistance.	*Phytopathol. Z.* 44:105-50, 1962.
153	Takebe I, Otsuki Y & Aoki S.	Isolation of tobacco mesophyll cells in intact and active state.	*Plant Cell Physiol.* 9:115-24, 1968.
147	Jenkins W R.	A rapid centrifugal-flotation technique for separating nematodes from soil.	*Plant Dis. Rep.* 48:692, 1964.
210	Large E C.	Growth stages in illustrations of the Feekes' scale.	*Plant Pathol.* 3:128-9, 1954.
64	Marre E, Lado P, Rasi Caldogno R & Columbo R.	Correlation between cell enlargement in pea internode segments and decrease in the pH of the medium of incubation. 1. Effects of fusicoccin, natural and synthetic auxins and mannitol.	*Plant Sci. Lett.* 1:179-84, 1973.

2595	Arnon D I.	Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*.	*Plant Physiol.* 24:1-15, 1949.
160	Johnson C M Stout P R, Broyer T C & Carlton A B.	Comparative chlorine requirements of different plant species	*Plant Soil* 8:337-53, 1957.
156	Jones R L & Varner J E.	The bioassay of gibberellins.	*Planta* 72:155-61, 1967.
38	Lichti-Federovich S & Ritchie J C.	Recent pollen assemblages from the western interior of Canada.	*Rev. Palaeobot. Palynol.* 7:297-344, 1968.
74	Whittaker R H.	Evolution and measurement of species diversity.	*Taxon* 21:213-51, 1972.
54	Geissbuhler H, Haselbach C, Abei H & Abner L.	The fate of N'-(4-chlorophenoxy)-phenyl-N, N-dimethylurea (C-1983) in soils and plants. 3. Breakdown in soils and plants.	*Weed Res.* 3:277-97, 1963.
176	Mohr H.	Untersuchungen zur Phytochrominduzierten Photomorphogenese des Senfkeimlings. (*Sinapis alba* L.) (Investigations on phytochrome induced photomorphogenesis in the mustard seedling.)	*Z. Pflanzenphysiol.* 54:63-83, 1966.
50	Melchers G.	Haploid higher plants for plant breeding.	*Z. Pflanzenzücht.* 67:19-32, 1972.

Table 5: Items cited 20 or more times by botany core journals in 1978.

Total Citations 1978	Cited Item
428	**Lowry O H, Rosebrough N J, Farr A L & Randall R J.** Protein measurement with the folin phenol reagent. *J. Biol. Chem.* 193:265, 1951.
145	**Arnon D I.** Copper enzymes in isolated chloroplasts: polyphenoloxidase in *Beta vulgaris*. *Plant Physiol.* 24:1, 1948.
122	**Murashige T & Skoog F.** Revised medium for rapid growth and bio-assays with tobacco tissue cultures. *Physiol. Plant.* 15:473, 1962.
90	**Spurr A R.** A low viscosity epoxy resin embedding medium for electron microscopy. *J. Ultrastruct. Res.* 26:31, 1969.
60	**Reynolds E S.** Use of lead citrate at high pH as an electron-opaque stain in electron microscopy. *J. Cell Biol.* 17:208, 1963.
55	**Davis B J.** Disc electrophoresis II. Method and application to human serum proteins. *Ann. NY Acad. Sci.* 121:404, 1964.
47	**Johansen D A.** *Plant microtechnique*. New York: McGraw-Hill, 1940. 523 p.
47	**Steel R G & Torrie J H.** *Principles and procedures of statistics with special reference to the biological sciences.* New York: McGraw-Hill, 1960. 481 p.
46	**Mabry T J, Markham K R & Thomas M B.** *The systematic identification of flavonoids.* Berlin: Springer-Verlag, 1970. 354 p.
43	**Jensen W A.** *Botanical histochemistry: principles and practice.* San Francisco: Freeman, 1962. 408 p.
43	**Linsmaier E M & Skoog F.** Organic growth factor requirements of tobacco tissue culture. *Physiol. Plant.* 18:100, 1956.
41	**Levitt J.** *Responses of plants to environmental stresses.* New York: Academic Press, 1972. 697 p.
41	**Weber K & Osborn M.** Reliability of molecular weight determinations by dodecyl sulfate-polyacrylamide gel electrophoresis. *J. Biol. Chem.* 244:4406, 1969.

37 **Dubois M, Gilles K A, Hamilton J K, Rebers P A & Smith F.** Colorimetric method for determination of vapors and related substances. *Anal. Chem.* 28:350, 1956.

37 **Esau K.** *Plant anatomy.* New York: Wiley, 1965. 767 p.

37 **Hsiao T C.** Plant responses to water stress. *Annu. Rev. Plant Physiol.* 24:519, 1973.

36 **Black C C.** Photosynthetic carbon fixation in relation to net CO_2 uptake. *Annu. Rev. Plant Physiol.* 24:253, 1973.

33 **Abeles F B.** *Ethylene in plant biology.* New York: Academic Press, 1973. 302 p.

33 **Gamborg O C, Miller R A & Ojima K.** Nutrient requirements of suspension cultures of soybean root cells. *Exp. Cell Res.* 50:151, 1968.

33 **Hoagland D R & Arnon D I.** The water-culture method for growing plants without soil. *Circ. Calif. Agric. Exp. Stn.* 347:1, 1950.

30 **Cronquist A.** *The evolution and classification of flowering plants.* New York: Houghton-Mifflin, 1968. 396 p.

27 **Bligh E G & Dyer W J.** A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.* 37:911, 1959.

27 **Davis G L.** *Systematic embryology of the angio-sperms.* New York: Wiley, 1966. 528 p.

27 **Feder N & O'Brien T P.** Plant microtechnique: some principles and new methods. *Amer. J. Bot.* 55:123, 1968.

27 **MacKinney G.** Absorption of light by chlorophyll solutions. *J. Biol. Chem.* 140:315, 1941.

27 **Miflin B J & Lea P J.** Pathway of nitrogen assimilation in plants. *Phytochemistry* 15:873, 1976.

27 **Raschke K.** Stomatal action. *Annu. Rev. Plant Physiol.* 26:309, 1975.

26 **Beevers L & Hageman R H.** Nitrate reduction in higher plants. *Annu. Rev. Plant Physiol.* 20:495, 1969.

26 **Laemmli U K.** Cleavage of structural proteins during assembly of the head of the bacteriophage-T4. *Nature* 227:680, 1970.

26 **Loening U E.** Fractionation of high-molecular weight ribonucleic acid by polyacrylamide-gel electrophoresis. *Biochem. J.* 102:251, 1967.

25 **Epstein E.** *Mineral nutrition of plants: principles and perspectives.* New York: Wiley, 1972. 412 p.

25 **Scholander P F, Hammel H T, Bradstreet E D & Hemmingsen E A.** Sap pressure in vascular plants: negative hydrostatic pressure can be measured. *Science* 148:339, 1965.

23 **Sokal R R & Rohlf F J.** *Biometry, the principles and practice of statistics in biological research.* San Francisco: Freeman, 1969. 776 p.

23 **Heber U.** Metabolite exchange between chloroplasts and cytoplasma. *Annu. Rev. Plant Physiol.* 25:393, 1974.

23 **Jensen R G & Bassham J A.** Photosynthesis by isolated chloroplasts. *Proc. Nat. Acad. Sci. US* 56:1095, 1966.

23 **Snedecor G W & Cochran W G.** *Statistical methods.* Ames, IA: Iowa State Univ. Press, 1967. 593 p.

22 **Bohlmann F, Burkhardt T & Zdero C.** *Naturally occurring acetylenes.* New York: Academic Press, 1973. 547 p.

22 **Derbyshire E, Wright D J & Boulter D.** Legumin and vicilin, storage proteins of legume seeds. *Phytochemistry* 15:3, 1976.

22 **Maheshwari P.** *An introduction to the embryology of angiosperms.* New York: McGraw-Hill, 1950. 453 p.

22 **Milborrow B V.** Chemistry and physiology of ascorbic acid. *Annu. Rev. Plant Physiol.* 25:259, 1974.

22 **Nelson N.** A photometric adaptation of the Somogyi method for the determination of glucose. *J. Biol. Chem.* 153:375, 1944.

22 **Takhtajan A.** *Flowering plants: origin and dispersal.* Washington, DC: Smithsonian Inst. Press, 1969. 310 p.

21 **Gaastra P.** Photosynthesis of crop plants as influenced by light, CO_2, temperature and stomatal diffusion resistance. *Meded. Landbouwhogesch. Wageningen* 59:1, 1959.

21 **Tolbert N E.** Microbodies: peroxisomes and glyoxysomes. *Annu. Rev. Plant Physiol.* 22:45, 1971.

20 **Chollet R & Ogren W L.** Regulation and photorespiration in C_3 and C_4 species. *Bot. Rev.* 41:137, 1975.

20 **Phillips I D J.** Apical dominance. *Annu. Rev. Plant Physiol.* 26:341, 1975.

other publications listed in Table 5 as old or older than Hoagland's paper. But they appear in well-known journals—*Journal of Biological Chemistry* or *Plant Physiology*—or they are books. Hoagland's paper stands out because it appeared in a circular distributed by a California agricultural experiment station. Non-journal publications, like circulars or monographs, may be an important channel for communication between botanical researchers. Levitt points out that monographs are among the most-cited references for some botanists, including himself. He says publishing in a monograph makes the research available to scientists who never read the botanical journal literature.[5]

It is most significant that the two other most-cited papers in Table 5 did in fact appear in plant physiology journals. Of the 46 cited items listed, 24 describe plant physiology research. Two items (both books) deal with the evolution of flowering plants. The remaining 20 items discuss statistical or chemical methods and plant anatomy. Again, the data in Table 5 support Levitt's opinion that plant physiology dominates botanical research.

* * * * *

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REFERENCES

1. **Garfield E.** Journal citation studies. 33. Botany journals, part 1: what they cite and what cites them. *Current Contents* (31):5-12, 4 August 1980.
2. --------------. Trends in biochemical literature. *Trends Biochem. Sci.* 4:N290-5, 1979.
3. --------------. Citation frequency as a measure of research activity and performance. *Current Contents* (5):5-7, 31 January 1973.*
4. **Heath I B.** Personal communication. 28 May 1980.
5. **Levitt J.** Personal communication. 27 May 1980.

*Reprinted in: **Garfield E.** *Essays of an information scientist.* Philadelphia: ISI Press, 1980. 3 vols.