

PERSPECTIVES

Survey of U.S. Land-Grant Universities for Training of Plant Breeding Students

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ABSTRACT

A survey was conducted to identify land-grant universities in the USA having plant breeding programs, and to determine the number of domestic and international plant breeding students graduating at the M.S. and Ph.D. levels from those programs in 1995 to 2000. A total of 71 U.S. land-grant universities were identified. There were 409 (53%) Ph.D. and 361 (47%) M.S. degrees awarded. Of the total, 362 (47%) graduates were domestic and 408 (53%) were international. There was no major change in the total number of plant breeding graduates during the 6-yr period. The largest numbers of plant breeding students were trained in agronomy (crop science) departments, followed by plant breeding departments or groups, horticulture departments, plant science departments, and combined agronomy-horticulture departments. Universities with an average of seven or more graduates per year were University of Wisconsin-Madison, North Carolina State University, University of Nebraska-Lincoln, Cornell University, University of Minnesota-St. Paul, Iowa State University, and Texas A&M University. The downward trend noted in previous surveys has continued to the point where there are only a few universities with large plant breeding programs remaining in each region of the country. If the USA is going to continue its public effort in plant breeding research and graduate student training, sufficient federal and state funding will have to be provided to support at least the current regional centers.

FOR THE PAST SEVERAL YEARS, there have been concerns in the public and private plant breeding sectors about the future availability of plant breeding graduates to work at seed companies and to fill other plant breeding positions (Collins and Phillips, 1991). Traditional plant breeding programs in U.S. land-grant universities have been diminishing as financial and human resources are reduced. Funding for plant breeding research and development today is in short supply in land-grant universities. From 1980 to the mid-1990s, 30 plant breeding positions (6% of the total) associated with graduate programs were eliminated. This downward trend has continued (Frey, 2000). Fewer land-grant universities are now involved in training students, and the remaining breeders are working with dwindling government support. The number of public plant breeding programs has declined during the previous few decades due to a lack of funds for agricultural research and to a redirection of funding to research in molecular genetics (Frey,

1996). Fewer plant breeders, working in fewer universities, are now providing the education and training for students interested in plant breeding. With a reduction in the number of training programs comes an increased need for planning to increase the number of plant breeding graduates. Planning is also needed to provide private industry with information on where its future workforce will come from.

Public sector agricultural research in general, and public plant breeding research in particular, is in trouble in both industrialized and developing countries. Budgets have leveled off, or are declining in the public sector. During the last 30 yr or more, private sector agricultural research investment has grown dramatically, and an increasing proportion of this investment has been directed to plant breeding (Heisey et al., 2001). Heisey et al. (2001) indicated that the main reasons for declining financial support in public plant breeding are scientific advance and the cost of research innovations.

Statistical data on federal funding for agricultural research and development show that government support in the USA has declined dramatically during the last half century. In 1940, nearly 40% of federal funding for research and development was allocated to agricultural research and development (Mowery and Rosenberg, 1989). By 1991, the USDA expenditure for research and development was only 2% of total federal research and development spending, and only 4% of federal research support at colleges and universities was devoted to agricultural research and development (Fugile et al., 1996). Federal funding for agricultural research and development increased at an annual rate of 2.8% until 1980, after which it has been nearly level (Frey, 2000).

Several surveys have been conducted during the past 17 yr to determine the number of plant breeding graduates from universities in the USA. Brooks and Vest (1985) conducted a survey of public programs on genetics and breeding of horticultural crops. The survey of 98 institutions projected a 13% decline in the number of horticultural plant breeders in the public sector from 1983 to 1990.

James (1990) reported that the U.S. public sector supported 417 plant breeders in 1989. That study reported 144 plant breeders in horticultural crop breeding, which was 19.6% less than the 179 horticultural crop breeders reported by Brooks and Vest (1985) in 1983. James (1990) pointed out that the number of plant breeding programs, as well as the number of plant breeders, had been declining across time. He suggested that programs on the improvement of minor crops would be most severely affected.

Collins and Phillips (1991) surveyed all public land-

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grant universities and 1890 universities on graduate training in plant breeding in the USA. They reported the number of plant breeders working on all crops was 477 in 1980, declining to 459 in 1989. This result showed that the loss of plant breeders was 1.8 per year during the 1980s. During the 10-yr period, the number of plant breeding programs decreased 9.3%, and the number of plant breeders decreased 3.9%. Collins and Phillips (1991) also indicated that changes in most states were relatively small, with California reporting the largest reduction in the number of plant breeding programs. However, a few states showed increases. During the 1980s, land-grant universities in Wisconsin, North Carolina, Texas, and Florida had the largest plant breeding programs.

The decline in public plant breeding programs has occurred in part because of the increase in private plant breeding programs. Kalton and Richardson (1983) surveyed private companies having plant breeding programs and reported that there were 1191 plant breeders in 1981. Kalton et al. (1989) conducted a second survey of private companies in 1988 and reported 1568 plant breeders, a 32% increase.

Frey (1996) conducted a survey on plant breeding research and development in the public sector as part of the U.S. National Plant Breeding Study and reported that the public sector decreased 2.5 scientist-years per year from 1990 to 1994. During the same period, private industry was found to have an annual net growth of 32 scientist-years with a gain of 2.4% per year. In a second study, Frey (1997) reported that the private breeding sector spent \$338 million annually on research and development, 61% of the U.S. annual expenditure on research and development of \$551 million, in 1994.

Collins and Phillips (1991) and Frey (1996) were concerned that the number of public plant breeders available to educate future plant breeders was on a slow and steady decline in the USA. From 1980 to 1994, there was a loss of 30 (full-time equivalent) public plant breeders (Frey, 1996). While oversupply of students can create problems for graduating students looking for appropriate jobs, the decline in public plant breeders along with the increase in private plant breeders appears to represent the opposite problem. To plan properly, universities should count the number of plant breeding students being trained, as well as plant breeders being hired by employers such as universities, USDA laboratories, seed companies, and food processors. Undergraduate students interested in graduate training in plant breeding need to know which universities have programs, and which programs are large enough to permit the teaching of courses in the various sub-areas of plant breeding. Small university programs are useful for training in niche areas.

Numerous surveys conducted between 1983 and 1997 indicated that there was a declining number of public plant breeders, and an increasing number of private plant breeders. Our survey was initiated to assess the current situation of plant breeding training in the public sector in the USA. The main objective of this survey was to identify land-grant universities in the USA that

have plant breeding programs, and to determine the numbers of plant breeding students at the M.S. and Ph.D. levels graduating from 1995 to 2000. We were also interested to know whether the students were in agronomy or horticulture, and whether they were domestic or international.

MATERIALS AND METHODS

In 2001, survey questionnaires were sent to all land-grant universities in the USA that were thought to have plant breeding programs. A total of 71 land-grant universities were identified in the USA. Of those, 51 had faculty and/or courses that could be used to offer plant breeding training leading to the M.S. or Ph.D. degrees. In the survey questionnaire, information was requested on the numbers of students trained from 1995 to 2000 in M.S. and Ph.D. levels for domestic and international plant breeding graduates. No sampling techniques were used since we counted every land-grant university. However, universities were asked to make a judgment when sending us the count of plant breeding students. We asked that they send us the count excluding graduate students working mostly in molecular genetics. It should be noted that the number of plant breeding degrees awarded is probably larger than the number of students graduating, since some students continue for a Ph.D. after receiving their M.S. degree.

The survey questionnaires were sent directly to departments in which plant breeding graduates could be trained. In land-grant universities, student counts of plant breeding graduates were requested from departments of horticulture or agronomy (crop science), as well as from combined agronomy and horticulture departments or general plant science departments. There were only two universities having either an official plant breeding department (Cornell University) or interdepartmental plant breeding program (University of Wisconsin-Madison). However, most large departments of agronomy or horticulture had a plant breeding group and/or a specialized plant breeding curriculum. Universities were assigned to a region of the USA based on the Cooperative State Research, Education, and Extension Service classification.

Information about the universities was obtained by university catalogs available in the library, as well as from the world wide web. We identified those universities having departments of horticulture, agronomy (crop science), plant science, combined agronomy and horticulture, or plant breeding. We then identified departments that offered courses or other training in plant breeding. Surveys were sent first by electronic mail (email) or telephone-transmitted facsimile (fax). The survey was resent to universities not responding to the first request. Telephone calls were used as a follow up for those not responding after three requests, and to clarify answers to the survey questions. Data obtained from the survey were summarized as means and frequencies.

RESULTS AND DISCUSSION

Responses were received from 78 departments offering plant breeding degrees representing 47 land-grant universities in 47 states. Seven states reported no degree programs in plant breeding and four states did not respond to survey. This resulted in a 95% return rate.

Number of Plant Breeding Graduates

During the survey years (1995 to 2000), 770 graduate degrees in plant breeding were awarded from 82 depart-

ments located at 47 land-grant universities (Table 1). There were 409 (53%) Ph.D. and 361 (47%) M.S. degrees awarded. Of the total, 362 (47%) graduates were domestic and 408 (53%) were international. Many of the universities reported having undergraduate programs, or at least courses, in plant breeding. However, most students entering graduate programs in plant breeding obtained their bachelor's degree in a biological science department including agronomy (or crop science), biology, botany, horticulture, or forestry.

Changes in the number of plant breeding degrees awarded during the 6-yr survey period were relatively small, with 1997 having the highest number of graduates and 1998 having the lowest (Fig. 1). The total number

Table 1. Numbers of plant breeding students trained at land-grant universities in the USA from 1995 to 2000.†

Land-grant university	Total	Domestic		International	
		Ph.D.	M.S.	Ph.D.	M.S.
<i>Total</i>	<i>770</i>	<i>153</i>	<i>207</i>	<i>258</i>	<i>152</i>
Univ. of Wisconsin-Madison	72	22	18	16	16
North Carolina State Univ.	64	7	21	26	10
Univ. of Nebraska-Lincoln	61	5	10	27	19
Cornell Univ.	54	18	5	27	4
Univ. of Minnesota	48	16	11	13	8
Iowa State Univ.	44	13	13	12	6
Texas A&M Univ.	41	9	10	18	4
Michigan State Univ.	36	10	12	8	6
North Dakota State Univ.	33	3	13	11	6
Oregon State Univ.	28	4	5	16	3
New Mexico State Univ.	25	4	6	10	5
South Dakota State Univ.	23	0	13	5	5
Kansas State Univ.	20	6	7	2	5
Mississippi State Univ.	20	6	4	6	4
Univ. of Puerto Rico	17	0	4	0	13
Washington State Univ.	17	1	7	4	5
Univ. of Florida	15	6	1	4	4
Auburn Univ.	15	1	3	5	6
Univ. of Idaho	15	3	7	3	2
Univ. of Illinois-Urbana	14	5	6	2	1
Purdue Univ.	14	2	3	6	3
Univ. of Missouri	13	0	5	8	0
Virginia Polytechnic Inst. & State Univ.	11	1	4	4	2
Louisiana State Univ.	8	0	4	3	1
Univ. of Hawaii	8	2	0	4	2
Univ. of Arkansas	7	2	2	3	0
Univ. of Maryland	6	0	3	2	1
Ohio State Univ.	6	1	1	1	3
Colorado State Univ.	5	0	1	3	1
Pennsylvania State Univ.	5	1	1	1	2
Univ. of California-Davis	4	1	2	1	0
Univ. of California-Riverside	4	0	2	1	1
Clemson Univ.	3	1	0	1	1
Univ. of Georgia	3	0	1	1	1
Univ. of Kentucky	3	2	0	1	0
Univ. of Connecticut	2	0	0	2	0
Univ. of Delaware	2	0	0	0	2
Univ. of New Hampshire	2	1	1	0	0
Univ. of Wyoming	1	0	0	1	0
Rutgers Univ.	1	0	1	0	0
Alabama A&M Univ.	0	0	0	0	0
Oklahoma State Univ.	0	0	0	0	0
Tuskegee Univ.	–‡	–	–	–	–
Univ. of Alaska-Fairbanks	0	0	0	0	0
Univ. of Guam	–	–	–	–	–
Univ. of Maine	0	0	0	0	0
Univ. of Rhode Island	0	0	0	0	0
Univ. of Tennessee	0	0	0	0	0
Univ. of Vermont	–	–	–	–	–
Virginia State Univ.	–	–	–	–	–
West Virginia Univ.	0	0	0	0	0

† Counts do not include students with primary training in molecular genetics.

‡ Not responding to survey, but probably zero.

of graduates in 1995 was similar to that in 2000. Overall, 1996 and 1997 had the most graduates, but otherwise the numbers were relatively constant. The same general trend can be seen in the numbers of M.S. and Ph.D. degrees awarded. The numbers of M.S. and Ph.D. graduates in 1995 and 2000 were similar.

For student origin, there were only small changes in the number of domestic and international plant breeding graduates across years. In 1995, the numbers of domestic and international graduates were similar. However, the total number of international graduates increased in 1996 and 1997. The trend then reversed, and in 2000, there were slightly more domestic graduates than international graduates (Fig. 1).

For degree, the trend was different than for total. The number of international Ph.D. graduates was significantly higher than the number of domestic Ph.D. graduates, as was the case in each year (Fig. 2). The number of international Ph.D. graduates increased greatly in 1996 and 1997. In general, the total number of international plant breeding Ph.D. graduates increased across years, while the total number of domestic Ph.D. graduates did not change much. There was a decrease in domestic Ph.D. graduates in 1999, but the number bounced back in 2000.

Major Centers for Plant Breeding Training

On the basis of the number of plant breeding students trained (Fig. 3), the top seven universities involved in plant breeding training were the University of Wisconsin-Madison, North Carolina State University, University of Nebraska-Lincoln, Cornell University, University of Minnesota-St. Paul, Iowa State University, and Texas A&M University. The geographical distribution of the top universities shows that the Midwest is a major region for the training of plant breeders in the USA (Fig. 4). Thus, each region of the USA had at least one major university offering plant breeding: Cornell University in the Northeast, North Carolina State University in the Southeast, University of Wisconsin-Madison (along with University of Minnesota-St. Paul and Iowa State University) in the Midwest, University of Nebraska-Lincoln (along with North Dakota State University) in the Great Plains, Texas A&M University in the South-central/Southwest, and Oregon State University in the West (Fig. 4). The major universities involved in plant breeding training have large programs that enable students to get a wide range of courses and practical training in the various areas of plant breeding, attracting a large number of students from the USA and abroad.

Departments Offering Plant Breeding Training

A total of 82 departments located in 51 land-grant universities offer plant breeding degrees and were surveyed in this study. Of all the departments surveyed, most were separate departments of agronomy (or crop science) and horticulture, each representing 34% of all departments (Fig. 5). Fewer departments were plant science (21%) or combined agronomy and horticulture (5%). Apparently, plant breeding programs operate

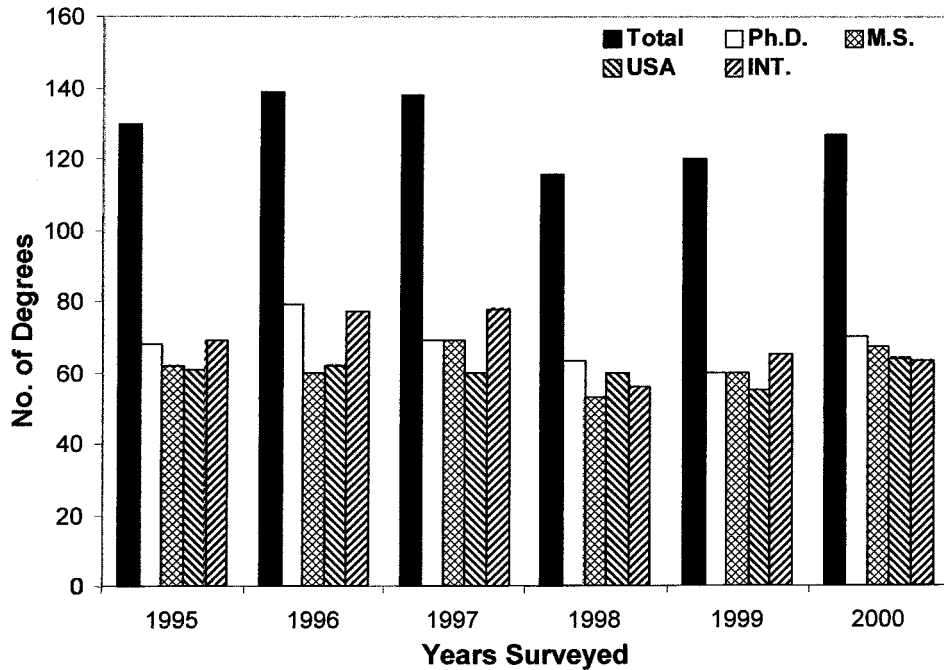


Fig. 1. Total degrees awarded in the USA at the M.S. and Ph.D. levels to plant breeding graduates from 1995 to 2000.

mainly in departments large enough to support a diversity of disciplines, mostly excluding the combined or general plant science departments having fewer agronomy or horticulture faculty.

The largest number of plant breeding students were trained in agronomy (crop science) departments, followed by plant breeding departments or groups, horticulture departments, plant science departments, and combined agronomy and horticulture departments (Fig. 6). Although plant breeding departments or groups

were only a small percentage of all departments, they were the second most important source of plant breeding student training.

Trends in Plant Breeding Graduates

Survey results showed that there were no major changes in the total number of plant breeding graduates during the past 6 yr in the USA, with only 2% more in 2000 than in 1995. The numbers fluctuated across years,

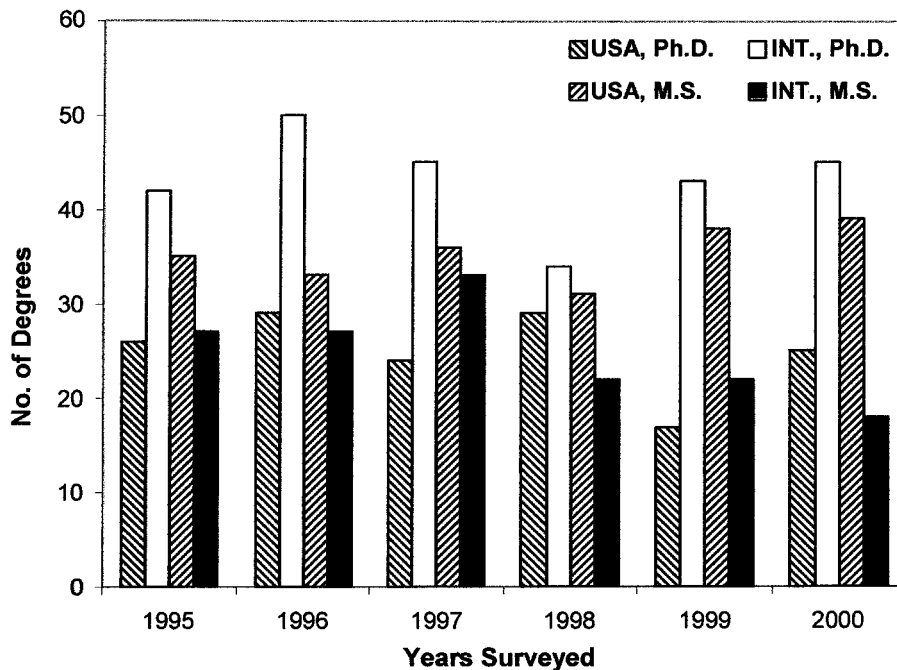


Fig. 2. Total degrees awarded in the USA for M.S. and Ph.D. levels for domestic (USA) and international (INT.) plant breeding graduates from 1995 to 2000.

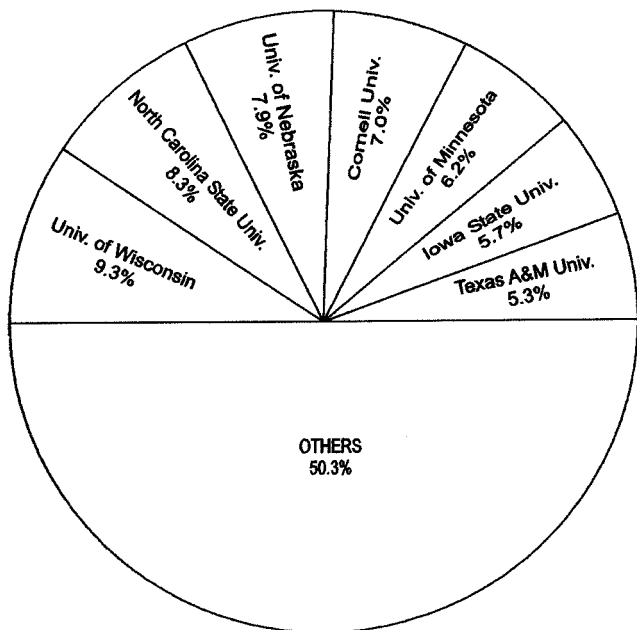


Fig. 3. Land-grant universities offering plant breeding training in the USA.

with an increase in the numbers of plant breeding graduates during 1996 and 1997. Some changes have occurred year-to-year in terms of the total numbers of domestic and international plant breeding graduates in the levels of M.S. and Ph.D. The number of domestic Ph.D. graduates remained steady, while the number of international Ph.D. graduates increased slightly. The number of domestic M.S. graduates had a large increase, while the number of international M.S. graduates declined.

A plant breeding training survey of public institutions was conducted by Collins and Phillips (1991), who reported that the number of plant breeding graduates

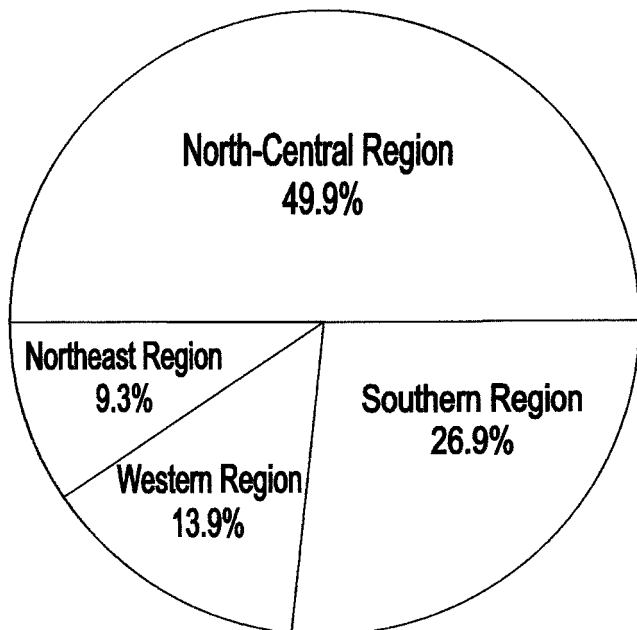


Fig. 4. Total number of plant breeding graduates by Cooperative State Research, Education, and Extension Service regions of the USA from 1995 to 2000.

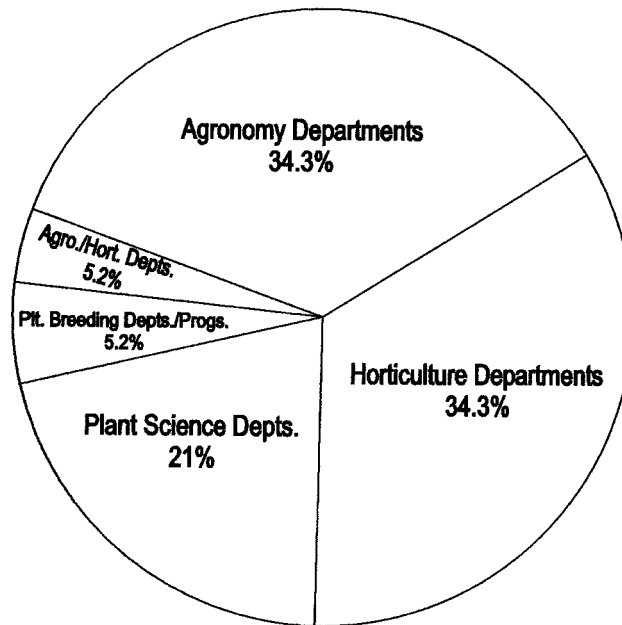


Fig. 5. Departments offering plant breeding degrees in U.S. land-grant universities.

declined slightly from 1980 to 1989. Hess (1989) concluded that the decline had bottomed out by 1989, and that some recovery had begun. Our survey results support the conclusion of Hess, showing a 2% increase in the number of plant breeding graduates from 1995 to 2000. Unlike the previous survey results, we found the number of domestic plant breeding graduates increased slightly while the number of international plant breeding graduates decreased.

General Comments from Survey

Telephone conversations with plant breeders revealed problems that were not obvious from the data collected in this survey. First, many plant breeders were operating with fewer resources than in the past. To increase their funding opportunities, breeders were moving to other crop species, or going into more basic areas of research. The reduced state funding and increased pursuit of other funding sources had the effect of reducing the amount of plant breeding work done on each crop. Second, many plant breeders were planning to retire in the next few years and thought that they would not be replaced, or if they were replaced, it would be with someone other than a plant breeder.

Comments received from public plant breeders were generally pessimistic about the future of breeding programs in land-grant universities. Some public plant breeders were well funded, especially those working on self-pollinated crops (such as small grains) or clonally propagated crops (such as sweet-potato, *Ipomoea batatas* var. *batatas*), where there was little private plant breeding effort. However, most plant breeders were not well funded and did not envision a change in the situation in the near future. The shift in government funding away from plant breeding and toward other areas such as molecular genetics has encouraged universities to

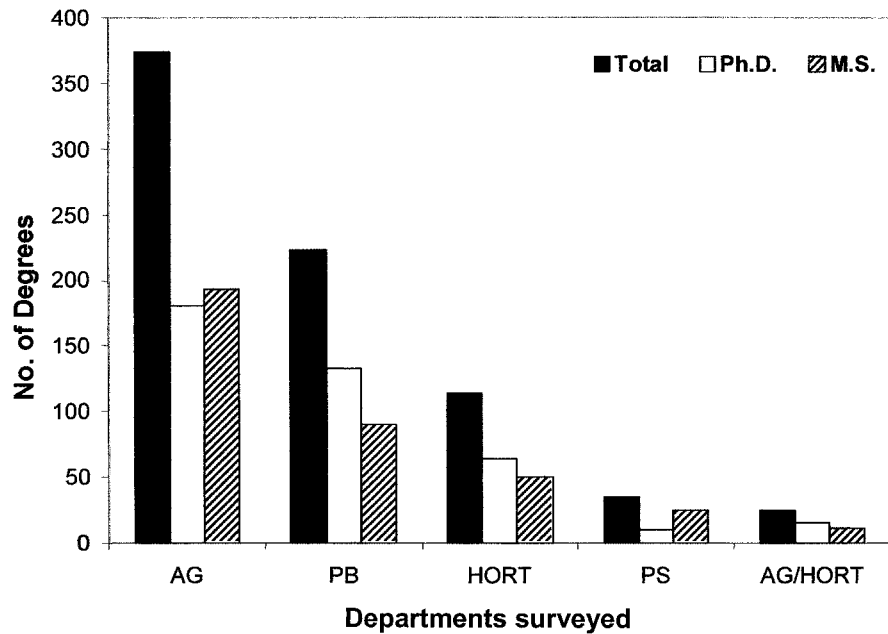


Fig. 6. Total number of plant breeding degrees awarded by all U.S. land-grant university departments from 1995 to 2000.

change emphasis in their crop research programs as plant breeders leave or retire. That shift can be seen at universities such as the University of California-Davis, which was formerly a leader in plant breeding but now has a much larger emphasis on molecular genetics.

The number of universities that have maintained a critical mass in plant breeding has been reduced almost to the point of having just one in each region of the USA. Also, some of the university programs, such as the University of Wisconsin-Madison, depend heavily on USDA-ARS scientists who have appointments as departmental faculty, but are supported by the federal government. Therefore, changes in federal support would have a large impact on some departments with graduate training in plant breeding. Universities often require at least six students to be registered for a class before it can be taught. Thus, universities that train fewer than six graduate students per year (all but the top eight universities) may have difficulty in offering their plant breeding courses in the future.

Departments in land-grant universities offer very different emphasis in subdisciplines and commodities, so it would be useful for prospective students to check the specializations of the departments of interest before applying for admission. For example, Washington State University has a large emphasis in the breeding of small grains, the University of Minnesota-St. Paul and Iowa State University are strong in the agronomic crops, and Cornell University, the University of Wisconsin-Madison, and North Carolina State University have programs in both agronomic and horticultural crops.

CONCLUSIONS

As the number of graduate students trained in plant breeding has declined during the last few decades, seed companies have considered hiring students with a B.S. in biological sciences, and then providing training in

plant breeding through company programs. This has been acceptable in some cases, particularly floricultural crop breeding, but has not been used at most seed companies. It appears that the downward trend noted in previous surveys has continued to the point where there are only a few universities in each region of the USA that provide training in plant breeding. The USDA advisory committee on agricultural biotechnology has recommended a significant increase in funding for public plant breeders (USDA, 2001). If the USA is interested in continuing the public effort in plant breeding research and graduate student training, sufficient federal and state funding will have to be provided to support at least the current regional centers.

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