RALPH M. CALDWELL

Annu. Rev. Phytopathol. 1993. 31:33–41

PIONEER LEADERS IN PLANT PATHOLOGY: RALPH M. CALDWELL [1]

John F. Schafer
Cereal Rust Laboratory, USDA-ARS, University of Minnesota, St. Paul, Minnesota 55108

KEY WORDS: cereal breeding, disease resistance, diversity, durable resistance

---

Ralph Caldwell was a dynamic, innovative plant pathologist and plant breeder. His contributions to small grain cereal production in the Eastern United States were at the top of his field, and his achievements brought respect and honor to the Purdue University/US Department of Agriculture small grain research and breeding program, which he led. His approach to scientific problems was incisive. Dr. Caldwell was practically oriented, never losing sight of the societal benefits of his work. Nevertheless, he was a strong participant in and supporter of more basic research—believing that it was essential but not the total answer. One of his guidelines was that the applied program—breeding for disease resistance—was central and required a team effort. It inevitably would run into problems that were not easily addressed in the ongoing team effort. These problems, in turn, became the objects of research studies, which were individually approached on second tracks by members of the "team." Research results were subsequently funneled back, as solutions for the specific problems, into the broadly based plant improvement program.

EDUCATION AND EARLY RELATIONSHIPS

Ralph Caldwell was born in Brookings, South Dakota, in 1903, and remained there through graduation in 1925 from what is now South Dakota State University (2). He then was a student in the University of Wisconsin Graduate

[1]The US Government has the right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper.

Table 1 Acreage, production, value, and increased productivity of Purdue-USDA soft red winter wheat cultivars, 1946–1985, in which Dr. Caldwell was involved in some stage of development.[a]

Cultivar	Years produced	Total acres (× 1000)	Total production (bu × 1000)	Total value, $ (× 1000)	Total increase over older Trumbull cultivar	
					Bushels	Value $m
Vigo	1946–1978	12 181	268 910	562 033	18.3	39.1
Knox	1953–1985	15 749	480 750	821 697	53.5	98.1
Dual	1955–1985	4 841	143 266	217 442	35.9	68.9
Vermillion	1955–1980	6 306	192 267	320 829	17.7	36.9
LaPorte	1957–1978	989	32 426	47 913	5.9	11.9
Monon	1959–1985	27 727	962 427	1 536 283	135.9	244.7
Redcoat	1960–1985	7 963	287 134	555 077	57.5	108.3
Reed	1962–1985	2 307	82 826	143 499	16.9	29.4
Knox 62	1962–1985	3 408	122 020	279 254	15.3	36.7
Riley	1965–1985	527	18 908	27 599	4.0	6.1
Benhur	1966–1985	2 617	95 912	140 089	22.7	35.0
Riley 67	1967–1978	84	3 075	4 429	0.6	0.9
Arthur	1968–1985	36 096	1 254 155	4 003 265	525.9	742.0
Arthur 71	1971–1985	26 778	1 072 479	3 493 199	330.6	783.2
Abe	1972–1985	11 094	456 230	1 529 818	201.5	528.0
Oasis	1973–1985	4 083	172 043	589 621	50.0	137.8
Downy	1976–1985	25	1 050	3 504	0.4	1.1
Beau	1976–1985	5 617	238 885	813 691	75.3	205.9
Sullivan	1977–1985	275	11 722	41 216	3.6	10.0
Auburn	1981–1985	745	32 011	102 213	12.9	42.5
Caldwell	1981–1985	3 994	172 371	542 630	56.8	178.5
Fillmore	1982–1985	86	3 719	22 590	1.3	3.8
Compton	1983–1985	259	11 291	33 872	4.0	12.6
Total		173 751	6 115 876	15 820 763	1646.5	3361.4

[a] Production and price values were calculated regionally based upon averages derived from individual state crop reports. These data are adapted from Roberts et al (16) with permission.

School, a contemporary and long-time friend and admirer of fellow plant pathology students, W. G. Snyder, R. G. Shands, and W. J. Zaumeyer. He maintained a life-long professional bond and continued communication with these other outstanding agricultural scientists. I mention this because throughout our association, he expressed his close ties with these early admired colleagues. The respect appeared to be mutual. May I quote from a 1964 letter to Dr. Caldwell from Dr. Zaumeyer, "Don't hedge—you always called a spade a spade when we were together at Madison and this is one of the reasons why you rated so high in my book. I'm sure you haven't changed." Dr. Caldwell received the Ph.D. degree from the University of Wisconsin and served a two-year stint as Wisconsin State Leader for Barberry Eradication.

In 1930 he replaced E. B. Mains (when the latter moved to the University of Michigan) in a US Department of Agriculture (nowadays Agricultural Research Service) position in charge of wheat leaf rust research, located at Purdue University. At this point, a long-term, extremely productive relationship was established with Leroy Compton, Dr. Mains' previous assistant. Ralph was an innovator in a hurry; "Comp" was a magnificent organizer. The combination worked well. Their interaction lasted until they retired in the early 1970s, some 40 years later. As he started his career at Purdue, Ralph undertook research in the biology of the rust pathogen (11) and evaluated losses due to the disease (7). With Comp's participation, he expanded the disease resistance breeding effort.

Dr. Caldwell resigned his position with the USDA in 1937 to become Head of the Department of Botany and Plant Pathology at Purdue University, a position he held for 17 years, while remaining a USDA Collaborator. With Comp's low-key organizational genius and Ralph's dynamic input, however, their productive relationship continued.

PROGRAM DEVELOPMENT

The program continued as a joint Purdue/USDA cooperative effort, as regularly identified on bulletin covers. The early years of research and plant breeding began paying off as wheat, oat, and barley cultivars started coming out at the other end of the research/breeding pipeline in the middle 1940s (16; Table 1), despite Dr. Caldwell's demanding administrative duties.

With the employment of Dr. Fred Patterson by the Department of Agronomy at Purdue University in 1950, two Purdue programs in cereal breeding were merged. This merger brought additional strength and broader-based institutional support to the unified endeavor, and increased already good administrative support. I had joined Ralph and Comp the previous year, to allow for greater departmental administrative effort on Dr. Caldwell's part. This merger of programs and expansion of staff solved a previous fragmentation problem, brought more efforts to bear, and evolved into a hardworking, productive team effort. As production of improved disease-resistant cultivars increased during the 1950s, our team became known informally as the "Big Four" of Purdue small grain development.

Ralph was always in a hurry. Like a good coach, he was also a great motivator of team effort and spirit. A major contribution was in providing the environment and leadership for a team approach. After grain harvest, the four of us spent much of the month of July together, planning crosses to be made the next year, getting a fall greenhouse series ready for vernalization, and making fall planting plans. Many decisions also were previously made quickly and decisively in the field. This phase was usually accomplished by two teams,

the oldsters and the then-kids. In the field, Ralph was a master at colorful descriptive language, which often to Ralph's mild chagrin, Comp would dutifully pass on to posterity in the field books. I imagine that these notebooks are still there on the shelves in Lilly Hall of Life Sciences. This two-team approach was often interspersed with full-team field review and consensus decisions. However, there was intensive seasonal pressure to get the job done on time, with plant growth and maturity and disease situations changing irretrievably on a daily basis, and massive amounts of breeding materials to cover. In fact, the work was at times spread out to more teams with other helpers, as demanded by the seasonal progression of crops and diseases. At least one newly arrived, newly married graduate student remembered being kept in the field along with the rest of the crew for long days, every day (weekends included) for at least a month after arriving directly from college graduation. Most of the current plant materials had to be discarded each year to make room for the new entries, derived from more recent crosses. After summer harvest, planting plans had to be made and seedlots prepared almost immediately for the fall planting of winter wheat, barley, and oats. This innovative impatience to move quickly through large volumes of breeding stocks produced three crops a year—two in the greenhouse and one in the field—even of winter grain crops. It provided the basis for one of Dr. Caldwell's commandments: (*a*) quickly set a routine and follow it, but (*b*) immediately set out to break that routine and establish a better one. This may have been the great complementation of "Doc's" and "Comp's" talents. In fact, the other three of us sometimes worked hard to keep Doc at his desk and out of the field during periods of tedious routine that we believed to demand timely implementation and allowed no time for interruption for innovation!

Ralph Caldwell was a pioneer in bringing in exotic germplasm to solve breeding problems. Under his leadership and with the need for disease-resistant germplasm, a wide range of plant parentage was brought into Purdue small grain breeding stocks. With rigorous selection of the resulting progenies, this diverse and massive germplasm base led to rapid improvement in breeding lines and subsequent cultivars. Comp's and Fred's skills for successfully making hybrids also greatly facilitated this effort. Ralph was a firm believer that disease resistance—his major arena—was of little direct value unless incorporated into productive cultivars. Thus, a quick progression was made from research to a massive breeding effort. To progress quickly without giving up the well-known, adapted base, and at the same time moving this base ahead to new levels of productivity and advantage, Ralph pioneered an adaptation of the backcross—hybridizing an exotic source to an adapted line and immediately backcrossing the hybrid to another adapted line. These adapted lines were seldom current cultivars but the most advanced, established

breeding lines, and likely a different one each time. This resulted in a "three-way cross" with two "doses" of adaptation to save the base and yet easy selection for the exotic characters to provide the progress. As most US wheat breeders and pathologists are well aware, this led to the lengthy, complex parentage designations for which Purdue lines soon became famous. There was a conscious focus on parent building as well as cultivar development itself.

Ralph was an early proponent of the principle of diversity—as important in breeding as in finances. He used this both in parentages, leading to the generally broad genetic base, and also in distinctly different cultivar releases, leading to diversity between farmers' fields (9).

He was also an opportunist. For example, the use of 'Chinese Spring' wheat as a leaf-rust resistant parent brought earlier maturity into many subsequent breeding lines of winter wheat without harm to winter hardiness. No one had asked for this earlier maturity, but once obtained it was treasured and not given up. This early maturity was established in Indiana agriculture with the 'Knox' cultivar in the early 1950s (6). Somewhat later, I well remember Ralph's excited reaction the day he and Comp discovered an even earlier, short, stiff-strawed line among tall, late rows, the line that later became the 'Monon' cultivar. Even this was not the end to such improvement in early maturity, as subsequent Purdue cultivars attest. Early maturity, based on the day-neutral reaction, greatly broadened the adaptation of Purdue-USDA cultivars. It also became the basis for wheat-soybean, double-crop production systems.

Ralph was willing and even eager to move into new research areas. For example, with the temporary control of leaf rust of wheat in Indiana in the 1950s, healthy green leaf tissue was available for attack by other fungi, specifically the *Septoria* species, which were quick to take this biological opportunity. Ralph, in turn, quickly redirected some of his research interests, primarily searching for adequately resistant parental materials (13). Even earlier, the losses of wheat from the Hessian fly were duly noted, and the resistance breeding efforts were expanded to incorporate this insect pest (4). In addition, productive research collaboration was started through Dr. Caldwell's initiative with USDA entomologists, W. B. Cartwright in the earlier years, and later for many years, with Dr. R. L. Gallun. This initial effort subsequently led to a major entomology research program at Purdue University. When the cereal leaf beetle descended on the United States in the early 1960s and its potential seriousness was as yet unknown, Dr. Caldwell encouraged a search for resistance that was quickly begun under the leadership of John Roberts, a long-time project colleague (17).

Along the way, Ralph pioneered efforts to improve the durability of disease resistance. Tolerance to cereal rusts was observed, studied, and documented

(10). Research by Romig & Caldwell (18) followed earlier field observations of differences among cultivars and among plant organs in resistance to penetration by rust fungi, suggesting that there might be a more "general" resistance than the classical hypersensitive type. Caldwell later became a leader in expressing the need for and availability of general resistance (3). In a keynote address at a symposium at the Northcentral Division of the American Phytopathological Society in 1967, Dr. Caldwell stated, "We try to think that we have a handle on an idea; we haven't"...We now know that it exists and works beautifully in some instances. We need to know the nature of such resistance so that we may identify it directly rather than by laborious epidemiological studies... Additional applause followed a comment that Dr. Caldwell's talk was one of the best evaluations of the disease situation in field crops ever heard. Much of his effort toward the end of his career was devoted to this objective of easily identifying and exploiting general or more durable types of resistance.

OUTREACH

Caldwell maintained a highly functional professional correspondence network with scientific colleagues. My memory recalls particularly J. G. Dickson, H. H. Flor, M. W. Gardner, G. W. Keitt, D. J. Samborski, and E. R. Sears. Caldwell worked quickly to adapt their scientific contributions to our program. One example is the introduction of the leaf rust resistance conditioned by *Lr* 9, developed by Dr. Sears, into Purdue wheat cultivars, beginning with 'Riley 67' (5) and continuing with 'Arthur 71' (8) and several others. Testing of breeding stocks developed in this effort was enhanced by the use of a leaf rust culture derived by Dr. Samborski.

Dr. Flor's travel schedule apparently brought him through Indiana almost annually for several years. I remember with considerable pleasure the stimulating discussions led by Caldwell and him during these visits, most particularly during the period prior to Flor becoming a "household" name in plant pathology.

Caldwell encouraged an openness about the Purdue program. Breeding stocks were shared with others in great quantities. Purdue wheat and oat pedigrees now show up in the parentages in numerous breeding programs.

In a letter to Dr. Zaumeyer in 1964 involving a discussion of "basic" and "applied" research, Caldwell stated, "The only criterion of acceptance of *Phytopathology* papers dealing with disease should be the degree of scientific excellence involved in the research and preparation of the manuscript." This seems to me to represent his view that all science (basic or applied) is good science as long as it *is* good science, and that applications when properly done are as important as the preceding research.

ADMINISTRATION AND STUDENT RELATIONSHIPS

As an administrator, Dr. Caldwell did not limit his developmental efforts to his own research areas. As department head, he initiated the Purdue research program in soybean diseases (1) in which Kirk Athow and Francis Laviolette subsequently spent their productive careers, and the apple scab resistance program that Ralph Shay and Ed Williams developed so successfully over many years (20), among others.

Caldwell was also a productive advisor of graduate students. He encouraged and challenged students to do their own thinking. However, in many instances their dissertation topics stemmed from problems that Caldwell had identified as needing solution in the breeding program. Useful results were quickly introduced as breeding techniques or goals back into the team program.

CONTRIBUTIONS AND HONORS

A biography of Dr. Caldwell was published in *Phytopathology* after his death in 1976 (2). It stressed his leadership in cooperation, bringing plant pathologists, agronomists, and entomologists into cooperative research and development efforts. Equally important was the establishment of a viable infrastructure for the interagency collaboration which worked so well with the Purdue/USDA-ARS relationship.

Caldwell was honored by being elected a fellow of the American Phytopathological Society, American Society of Agronomy, Crop Science Society of America, and American Association for the Advancement of Science. He was also honored with awards from South Dakota State University, the Purdue Agricultural Alumni Association, and the Indiana Crop Improvement Association. Successors in the program named wheat cultivars after both Caldwell and Compton in the 1980s (14, 19; Table 1). Caldwell served the American Phytopathological Society in several official capacities, including President of its Northcentral Division and Treasurer/Business Manager.

Ralph Caldwell was a dynamic, innovative plant pathologist. He made numerous research contributions. Administratively, he succeeded in initiating several outstanding programs subsequently conducted by others. Perhaps his greatest contributions, however, were in applied cereal breeding with major emphasis on disease resistance, but without ignoring the other fundamental breeding needs. By 1974, Purdue/ARS soft red winter wheat cultivars led wheat production in 17 Eastern states, comprising more than 50% of the acreage in 14 of these states (15). In 1965, Purdue/ARS oat cultivars accounted for 19% of the spring oats certified for seed in the United States (12). A measure of the productivity in wheat breeding for which Caldwell laid much of the early groundwork and to which he contributed leadership and

participation for many years is assembled in Table 1 (adapted from 16). This compilation indicates that the wheat cultivars alone, for which Dr. Caldwell was a major developer, contributed more than three billion dollars in increased productivity of American agriculture over cultivars available prior to their release—quite a measure of the societal benefits of the research and development efforts led or initiated by this talented scientist.

ACKNOWLEDGMENT

I appreciate suggestions on the manuscript from R. J. Green Jr., T. Kommedahl, R. F. Nyvall, F. L. Patterson, J. J. Roberts, and R. W. Romig. R. J. Green Jr. provided the photo from the Department of Botany and Plant Pathology at Purdue University. Rosalind Richards' contributions were invaluable in successive typings.

Literature Cited

1. Athow, K. L., Caldwell, R. M. 1954. A comparative study of *Diaporthe* stem canker and pod and stem blight of soybean. *Phytopathology* 44:319–25
2. Athow, K. L., Green, R. J. Jr., Schafer, J. F., Shaner, G. 1977. Ralph Merrill Caldwell, 1903–1976. *Phytopathology* 67:1317
3. Caldwell, R. M. 1966. Advances and challenges in the control of plant diseases through breeding. *USDA/ARS* 33–110:117–26
4. Caldwell, R. M., Compton, L. E., Cartwright, W. B., Schafer, J. F., Patterson, F. L. 1957. Utilization of the W38 resistance of wheat to Hessian fly. *Agron. J.* 49:520
5. Caldwell, R. M., Compton, L. E., Patterson, F. L., Schafer, J. F., Gallun, R. L. 1967. Riley 67 soft red winter wheat, resistant to leaf rust and loose smut. *Purdue Univ. Agric. Exp. Stn. Res. Prog. Rep.* 309. 3 pp.
6. Caldwell, R. M., Compton, L. E., Schafer, J. F., Patterson, F. L. 1954. Knox, a new leaf rust resistant and stem rust escaping soft winter wheat. *Phytopathology* 44:483–84 (Abstr.)
7. Caldwell, R. M., Kraybill, H. R., Sullivan, J. T., Compton, L. E. 1934. Effect of leaf rust (*Puccinia triticina*) on yield, physical characters, and composition of winter wheats. *J. Agric. Res.* 64:1049–71
8. Caldwell, R. M., Roberts, J. J., Finney, R. E., Shaner, G. E., Patterson, F. L., et al. 1972. Arthur 71 soft red winter wheat, improved for resistances to leaf rust and Hessian fly. *Purdue Univ. Agric. Exp. Stn. Res. Prog. Rep.* 406. 3 pp.
9. Caldwell, R. M., Schafer, J. F., Compton, L. E., Patterson, F. L. 1957. A mature-plant type of wheat leaf rust resistance of composite origin. *Phytopathology* 47:691–92
10. Caldwell, R. M., Schafer, J. F., Compton, L. E., Patterson, F. L. 1958. Tolerance to cereal leaf rusts. *Science* 128:714–15
11. Caldwell, R. M., Stone, G. M. 1936. Relation of stomatal function of wheat to invasion and infection by leaf rust (*Puccinia triticina*). *J. Agric. Res.* 52: 917–32
12. Garrison, R. H., Black, D. G. 1965. Report of seed certified in 1965 by state certifying agencies. *Int. Crop Imp. Assn. Prod.* Publ. 13
13. Narvaez, I., Caldwell, R. M. 1957. Inheritance of resistance to leaf blotch of wheat caused by *Septoria tritici*. *Phytopathology* 47:529–30 (Abstr.)
14. Patterson, F. L., Ohm, H. W., Shaner, G. E., Finney, R. C., Gallun, R. L., et al. 1981. Caldwell soft red winter wheat. *Purdue Univ. Agric. Exp. Stn. Bull.* 328. 16 pp.
15. Reitz, L. P., Hamlin, W. G. 1978. Distribution of the varieties and classes of wheat in the United States in 1974. *USDA Stat. Bull.* 604. 98 pp.
16. Roberts, J. J., Foster, J. E., Patterson,

F. L. 1988. The Purdue-USDA small grain improvement program—A model of research productivity. *J. Prod. Agric.* 1:239–41

17. Roberts, J. J., Patterson, F. L., Gallun, R. L., Hendricks, L. T., Finney, R. E., et al. 1976. Downy soft red winter wheat, resistant to the cereal leaf beetle. *Purdue Univ. Agric. Exp. Stn. Bull.* 115. 3 pp.
18. Romig, R. W., Caldwell, R. M. 1964. Stomatal exclusion of *Puccinia recondita* by wheat peduncles and sheaths. *Phytopathology* 54:214–18
19. Shaner, G. E., Ohm, H. W., Foster, J. E., Patterson, F. L., Day, K. M., et al. 1984. Compton soft red winter wheat. *Purdue Univ. Agric. Exp. Stn. Bull.* 448. 14 pp.
20. Shay, J. R., Williams, E. B., Janick, J. 1962. Disease resistance in apple and pear. *Am. Soc. Hortic. Sci.* 80:97–104