

A History of Weed Control in the United States and Canada¹

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Available literature indicates that relatively few agricultural leaders and farmers became interested in weeds as a problem before 1200 A.D. or even 1500 A.D. For many centuries, weed control was mostly incidental to tillage for seedbed preparation and growing of crops and to growing and cutting or pasturing of thickly planted crops. Occasional references in literature previous to 1900 mentioned use of mechanical devices and a few inorganic herbicides specifically for weed control.

State weed laws directed at control of plant diseases were enacted during 1721 to 1766, but weed and seed laws involving weeds directly were not enacted until 100 to 200 years later. Only a few extension type publications on weeds were issued in the United States and Canada between 1860 and 1900. There was a rapid increase in such publications after 1900. Research with inorganic chemicals as herbicides was begun in the 1890's in Europe and in a few states and provinces, and was increased at a rapid pace until the early 1940's. New developments in mechanical and biological control of weeds increased steadily during the same period. However, weed control remained a relatively minor phase of agronomy, botany, horticulture, agricultural engineering, and plant physiology until the early 1950's.

About 10 years after the discovery of (2,4-dichlorophenoxy)acetic acid (2,4-D) in 1942–1944, the much increased interest of scientists, federal and state governments, industrial companies, and the general public had begun to bear fruit. The word “weed” or “weeds” began to appear in the titles of college courses and extension specialists. Weed conferences had been organized in six regions of the United States and Canada and in 10 states.

The first meeting of the Weed Science Society of America was held in 1956 and Weed Science was adopted as its official journal. The number of herbicides in general use in the United States and Canada increased from 15 in 1940 to 25 in 1950, and to 100 in 1969. The total support for weed research in 1962 in the United States was six times that in 1950. The number of full-time research and extension workers or their equivalents in part-time workers had increased 20-fold and 13-fold, respectively, over the number in 1940.

The rate of advancement in the art and science of weed control has increased so rapidly that the progress in each of the recent brief periods 1941 to 1968, 1901 to 1940, and 1800 to 1900 is considered greater than that in all previous periods, beginning about 6000 B.C.

Introduction

THE inspiration for this review article came from responses to papers by the author on the history of weed control presented at a state weed conference in 1963 and a regional weed conference in January 1969. The numerous unfilled requests for copies of those papers indicate that many weed specialists, who have been busy with current responsibilities and future challenges, are beginning to wonder about the history and heritage of their art and science. Weed control is one of the youngest of sciences but a relatively old art. It has a heritage worthy of much pride.

In a brief review article covering events during thousands of years, only the most significant events and a few of the individual workers, mostly pioneers, can be mentioned. Emphasis is given to events, mostly firsts, prior to 1950 and some of the outstanding men involved in those events. Some mention is made of de-

velopments before 1920 in countries outside the United States and Canada. The significant events since 1950, mostly firsts, are mentioned with none or only a brief discussion of the most outstanding developments.

My career in weed research began in 1935 at age 30. That was an ideal age and time from which to look back to earlier developments in weed control, and at which to evaluate the current status of and the general attitude toward weed control. It also afforded me the opportunity to experience or observe the rapid changes and remarkable progress in the art and science of weed control that have occurred during the past 34 years.

Weeds and Their Control Prior to 1800 A.D.

The first man, Adam, was promised thorns and thistles (Genesis 3:18). Man probably has been plagued by weeds from the beginning. However, available evidence and logic indicate that early man did not consciously or intentionally practice weed control. According to H. G. Wells (185), primitive agriculture was begun by neolithic man some time

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between 15,000 and 10,000 B.C. Man was first a hunter and a forager. He gathered his plant food from those plants growing naturally, and which he learned were edible and not harmful. His foraging was more sophisticated than that by cattle (*Bos* spp.), goats (*Capra* spp.), and most other herbivorous animals of that time only because he could use his hands as well as his mouth.

The first actual planting of crops probably was the growing of primitive wheat (*Triticum* spp.) in small patches near the temporary settlements of nomadic hunter tribes. Most of the crops probably were grown on periodically flooded land near rivers or in other areas where wild plants (weeds) were less numerous and the soil was fertile and well watered. It is possible but unlikely that hand-weeding was practiced to remove unwanted plants from these primitive crops before harvest.

The development of irrigation along the Euphrates and Tigris Rivers in Mesopotamia and the Nile River in Egypt about 6500 B.C. probably marked the beginning of stabilized agriculture (185). Drawings made as early as 6000 B.C. in ancient Egypt and Mesopotamia show a V-shaped portion of a tree apparently tipped with bronze and used in a manner similar to our modern hoe or mattock (71). That implement probably was used primarily for stirring the soil and planting, rather than deliberately for weed control. If this implement was used intentionally for weed control, it probably was preceded by hand-weeding by women while the men were hunting.

The hand sickle was invented about 3000 B.C. (71) and probably was constructed of bone or wood. The scythe and the cradle were invented much later. All of these implements were used first for harvesting crops. Records of their early use for weeding were not found.

By 1000 B.C., man had developed a T-shaped wooden implement which was pulled by cattle or slaves. About 500 years later, some innovating agriculturist invented a drag harrow from a tree limb with short stubs of branches for teeth. By the first century A.D., the harrow had been improved to consist of an A-shaped log drag with wooden pegs driven through holes in the logs to form teeth. By 1000 A.D., the invention (71) of the collar made it possible to use horses (*Equinus* spp.) as motive power.

It seems possible, even probable, that weed control was rare as an intentional practice even as late as early Roman times. Some of the earliest references to undesirable plants in literature are in the Holy Bible. Jonah had trouble with waterweeds before his experience with the whale (Jonah 2: 5). Two parables of Jesus recorded in the New Testament (Matt. 13:3–8, 24–30) mention crop seeds which fell among the thorns and were choked, and tares (weeds) which were planted in the wheat by an enemy at night. In both cases, no effort was made to remove the weeds from the crop before harvest. However, a Roman writer in the first century A.D.³ recognized that, if weeding is neglected, the produce of fields will be greatly diminished. Occasional mention was made by other early Roman writers on use of metal-bladed hoe like implements for weeding in addition to more common uses for digging, seedbed preparation, and planting (188). It seems possible that Chinese and Indian literature might contain earlier references to weed control.

³ Dickson, Adam. 1788. *Husbandry of the ancients*. See Clark and Fletcher (39), p. 55.

Clark and Fletcher (39) included many quotations on weeds and weed control from early British publications. A law in Scotland during 1212 to 1249⁴ decreed severe penalties to tenants or bond servants who seeded weeds on the land or who did not destroy certain weeds. The enforcement was so effective that the weeds were practically eliminated; the area became famous for cereal grains free from weed seeds. “Gool riders” could no longer find enough weeds and collect enough fines to afford a dinner or a drink.⁵ Sinclair in 1814⁶ described those early regulatory practices in parts of Scotland and suggested the need for their renewal.

Several British writers in the 16th, 17th, and 18th centuries discussed the nature of weeds as then understood and the problems caused by them. The poetic agricultural writer, Thomas Tusser, stated in 1557, “Who weeding slacketh, good husbandry lacketh.”⁷ Shakespeare mentioned weeds disparagingly in at least six of his plays written in 1592 to 1599.⁸ Bacon, in 1625,⁹ expressed many ideas about weeds, some of which would be considered superstitions today. Blith, in 1652,¹⁰ Tull, in 1731,¹¹ Hale, in 1756,¹² and Dickson, in 1785,¹³ were more knowledgeable about weed control and the nature of weeds by modern standards. Hale’s definition of a weed was similar to ours today. Jethro Tull was a crusader against weeds and urged their extermination from Britain.

However, the general philosophy appeared to be that weeds were a curse which must be endured, and about which little could be done except by that which was incidental to crop production, and by the laborious supplemental hand methods. Remnants of that philosophy were still present in the United States in the early 1900’s.

Early Mechanical Developments in Weed Control

Gittins (71) assembled a complete history of the development of equipment in agriculture. By 1617, the English had developed an improved wood plow with an iron pointed share that somewhat resembled the moldboard plow with an iron shear patented by Thomas Jefferson in 1797. An all-steel plow was in use by 1837. Chilled steel moldboard and shares, used first in 1869, constituted an ultimate in early plow improvement. While improvement in the plow was a symbol of progress in agriculture, it was not a certain

⁴ Statute of Alexander II of Scotland 1212–1249. See Clark and Fletcher (39), p. 23.

⁵ Cargill, P. *Perths-Statist. Ace.* 12,536,537. *Jameson’s Scottish Dictionary*. See Clark and Fletcher (39), p. 45.

⁶ Sinclair. 1814. *System of husbandry*. See Clark and Fletcher (39), p. 159.

⁷ Tusser, Thomas. 1557. *Five hundredth pointes of husbandrie*. See Clark and Fletcher (39), p. 177.

⁸ Shakespeare, William. 1592 to 1599. 2 Henry VI, Act III, Scene 1, and five other plays. See Clark and Fletcher (39), p. 49, 58, 79, 91, 118, 131.

⁹ Bacon, Francis. 1625. *Natural history*. See Clark and Fletcher (39), p. 27, 35, 71, 119, 125, 129, 135, 151, 175.

¹⁰ Blith, Walter. 1652. *The system of husbandry surveyed*. See Clark and Fletcher (39), p. 85, 145.

¹¹ Tull, Jethro. 1731. *The horse hoeing husbandry*. See Clark and Fletcher (39), p. 43, 67, 137, 177.

¹² Hale, Thomas. 1756. *The compleat body of husbandry*. See Clark and Fletcher (39), p. 37, 39, 131, 133, 175.

¹³ Dickson, Adam. 1785. *A treatise on agriculture*. See Clark and Fletcher (39), p. 58, 149.

indication of equal progress in weed control. However, in 1777, Gadd mentioned use of the plow as the chief means of weed control in Sweden (68).

A horse-drawn "hoe," developed in Britain about 1722 by Jethro Tull,¹¹ probably was better adapted for weed control than the plow, even though the intended function of the hoe was for pulverizing the surface soil so that "the needed soil elements could be absorbed more readily by plant roots."

The invention of the wheel cultivator with steel shovels in 1848 (71), of the straddle row cultivator in 1856, and of the riding cultivator in the 1880's were distinct milestones in the progress in weed control during the early part of the horse-power era which began about 1850. The two-wheel mower came into use in the 1850's, mostly for harvesting hay and grain. It probably came into use for intentional weed control much later. The springtooth harrow and the rotary hoe were significant advances in horse-drawn implements. The invention of Allen's push-and-pull hoe in 1866 was an important innovation (173).

The self-propelled steam tractor invented in the 1850's (71) and used rather extensively by 1880 never provided much competition with horse-power, especially in weed control. The gasoline tractor was in the early stage of development by 1910, but did not compete with horsepower or become an important factor in agriculture or weed control until about 1920.

The hand sprayer, developed in the 1850's, and the tractor sprayer, invented in 1887, were used first for disease and insect control and not used for weed control much, if at all, before 1900. Gasoline-powered sprayers came into use for control of insects and diseases beginning in 1900, but were not used for weed control to any extent before 1930. On the other hand, a series of gasoline-powered crusher boats were used rather extensively by the U.S. Army Corps of Engineers during 1900 to 1937 for control of waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) in Louisiana.¹⁴

Horse and tractor-drawn disks, chains, and various drags were used to remove aquatic weeds from irrigation ditches, probably as early as 1900 and extensively until 1950¹⁵ (176). Mechanical removal of aquatic weeds followed earlier hand means. The latter continued along with mechanical methods to a diminishing extent.

From 1890 to 1911, research on soil aeration and the dust mulch for moisture conservation proved that the doubts raised about these practices were valid. Experiments in New York in 1888 to 1890, Missouri in 1889 to 1890, South Carolina in 1898 to 1899, and in Utah in 1890 to 1897 and 125 experiments by the U.S. Dept. of Agr. in 28 states showed that normal cultivation of corn (*Zea mays* L.) plus pulling remaining weeds produced no greater yields than did surface hoeing to remove weeds without cultivation (34). However, later research^{15a} in Illinois and Ohio showed that, on certain heavy soils, cultivation increased rainfall penetration and resulted in higher crop yields.

The rodweeder, developed in the Pacific Northwest during 1912 to 1914 (71), was the first field implement to be

designed exclusively, or even chiefly, for weed control. The tractor-mounted cultivator, developed in the early 1920's, and the duckfoot and blade cultivators in the late 1920's and the 1930's signaled the rapid transition from horse-power to tractor power in weed control and most other phases of agriculture. The urgent need for such implements resulted in many homemade models (200).

Beginning in 1925, new developments in mechanical weed control occurred much more rapidly. The airblast mist blower was introduced in 1925 (71), jet-type pumps in 1926, and the tractor-mounted sprayer in 1930. Probably, none was used for weed control until the 1940's. Oil and liquid propane gas burners came into use for weed control on ditchbanks and other non-cultivated areas in the late 1930's and soon were in extensive use, especially in southwestern states (24, 40, 176). The flame cultivator came into use in the early 1940's for selective weeding in cotton (*Gossypium* spp.) and certain other row crops (14, 61, 131). The history of flame cultivation and its current status for weed control was reviewed in 1964 (130). In 1940, several granule spreaders adapted from fertilizer spreaders were introduced for applying sodium chlorate and other granular herbicides.¹⁶

Several versions of an "electrovator" for control of deep-rooted perennial weeds by electricity were promoted during the 1940's with sporadic profits by promoters but little success in weed control (95). Electricity was suggested for control of johnsongrass (*Sorghum halepense* (L.) Pers.) as early as 1901 (12).

During the 1940's, the airplane sprayer and the ground-based mist blower previously used for control of cotton and forest insects were first used for application of herbicides. During the late 1940's and early 1950's, low-pressure, low-volume sprayers and nozzles were developed for ground and aerial equipment to apply the new phenoxy herbicides. Band-applicators were devised for preemergence and pre-planting applications of granule and liquid herbicides in row crops (71). Boom-jet nozzles came into use for supplementing or replacing conventional spray booms on ground rigs for broadcast spraying.

Many more improvements were made during the 1960's in placement and subsurface application of granule, spray, and other formulations of herbicides in row crops¹⁷ (16, 119, 166, 198). Numerous new innovations were made in aerial equipment for applying herbicides.

Early History of Herbicides

Man apparently practiced control of insects and plant diseases, especially with chemicals, much earlier than he did weed control. The Greek poet Homer, in 1000 B.C., (129) wrote of "pest-averting sulfur" more than 2,500 years before the publication by Thomas Tusser and 2,840 years before the first recorded use of salt for weed control. In 470 B.C., Democritus recommended an extract of the olive (*Osmanthus* spp.) for the control of blight. In 60 A.D., the Roman agricultural writer Pliny recommended soaking wheat seed

¹⁴ Wunderlich, W. E. 1961. History of waterhyacinth control. Mimeo Pub. U.S. Army Corps Eng., New Orleans District. 5 p.

¹⁵ Balcom, Robert B. 1943. Preliminary survey of aquatic weed problem in irrigation systems. U.S. Dep. Interior Mimeo Pub. 19 p.

^{15a} Correspondence from C. J. Willard, October 1969.

¹⁶ Correspondence from E. S. Gandrud, Gandy Co., Inc., Owatonna, Minnesota, 1964.

¹⁷ Barrentine, W. L. and C. G. McWhorter. 1966. New spray techniques for directed postemergence weed control in row crops. Weed Sci. Soc. Amer. Abstr. p. 104.

in wine to prevent mildew. Control of plant disease with sulfur began in 1850 and large-scale operations of Paris green for control of insects were begun in the United States in 1867 (129).

Mukula and Ruuttunen (128) and Blackman (20) gave brief summaries of the early history of herbicide developments in Europe and North America. Hildebrand (90) discussed early herbicide developments, mostly in the United States. Lime was recommended for control of horsetail (*Equisetum* sp.) in Germany in 1840.¹⁸ The use of salt (sodium chloride) as a herbicide was recommended in Germany in 1854,¹⁹ but it probably was used as a herbicide much earlier. Salt was tested for control of orange hawkweed (*Hieracium aurantiacum* L.) (102) in Vermont as early as 1896. It was first tested for control of field bindweed (*Convolvulus arvensis* L.) in Kansas in 1915 (31). Salt was used extensively for field bindweed control on highway and railroad rights-of-way in Kansas during 1937 to 1950 (201). The usual rate was 20 tons/A. Hundreds of carloads were used annually.

Kirchhof in 1855²⁰ recommended sulfuric acid and iron sulfate against weeds in Germany. He also discussed the use of selective weed control as did other German writers a few years later.

Copper sulfate was first used for selective weed control of charlock (*Brassica kaber* (DC.) L. C. Wheeler) in wheat by the French in 1896.²¹ Within the next 3 years, one or more of the chemicals copper sulfate, iron sulfate, sulfuric acid, and nitric acid were tested for control of annual forbs in cereals by other workers in France,²² Germany,²³ Canada (77), and the United States (21, 22, 178). Neither copper sulfate nor iron sulfate proved satisfactory for control of weeds in crops. On the other hand, copper sulfate has been the most widely used algacide in the United States since 1905 (125, 135).

Sulfuric acid was used by the French for control of annual forbs in cereals in 1911.²⁴ It was tested earlier in Canada and the United States alone and in combination with iron and copper sulfates (87, 99, 178, 182). By 1935, sulfuric acid was being used in the United States for weed control in onions (*Allium cepa* L.) and, to some extent, in cereals (9, 13, 88).

The arsenicals were the first chemicals to be tested widely for weed control and to gain rather general use as herbicides. Sodium arsenite was used rather extensively by the Army Corps of Engineers²⁵ for control of water hyacinth in Lou-

isiana from 1902 to 1937 despite the chemical's toxicity hazard to humans, livestock, and wildlife.

Sodium arsenite was used extensively in Hawaii for controlling annual weeds, particularly forbs, during 1913 to 1945 (83). In 1917, George Gray in California (74) demonstrated that sodium arsenite moved rapidly from field bindweed foliage to the roots under conditions of high air humidity and dry soil. This early evidence of translocation stimulated considerable use of the acid arsenical method of controlling field bindweed and other perennial weeds and brush by 1930 (43, 152). In 1926, sodium arsenite was found highly effective on submersed aquatic weeds in Wisconsin lakes (57). After that time, sodium arsenite continued to be a widely and extensively used aquatic herbicide in lakes and farm ponds (116, 165).

The effectiveness of carbon bisulfide as a soil fumigant for weed control was discovered in 1906 (184) and 1909 (190). By 1913 to 1925, that chemical was in rather general use in California and Hawaii (82). The most extensive use of carbon bisulfide was in Idaho (163) where 350,000 gallons was applied in the peak year of 1936.

Orchard heating oil was used for control of garlic (*Allium tricoccum* Ait.) and wild onions (*Allium canadense* L.) as early as 1914 (56, 144, 158). Beginning in 1919 and through the 1940's, the petroleum herbicides became increasingly important for control of weeds on ditchbanks and in other non-crop areas²⁶ (176) and for selective weeding of carrots (*Daucus carota* L.), parsnips (*Pastinaca sativa* L.), dill (*Anethum graveolens* L.), and cotton (75, 76, 166). The effectiveness of emulsified xylene-type aromatic solvents for control of submersed aquatic weeds in flowing water was discovered by Agricultural Research Service and Bureau of Reclamation scientists in 1948 (28, 124). Since then, that chemical has become by far the most extensively used herbicide for controlling submersed weeds in irrigation and drainage ditches of the 17 western states (28, 175).

Sodium chlorate, first used for weed control in France in 1923 (114), was being tested rather intensively in New York (8, 10), Kansas (107), Nebraska (105), Ohio (186, 191), Washington (159), and probably a few other states during 1925 to 1930. Despite its rather high cost and serious fire hazard, sodium chlorate increased rapidly in use, chiefly for control of deep-rooted perennial weeds in non-crop areas and small patches in cultivated fields (42, 100, 101, 112, 127). Idaho used a total of 4 million pounds of chlorate from 1927 to 1935 (100). Kansas used nearly 3 million pounds annually during 1939 to 1940 (201).

The phytotoxicity of boron compounds to plants was known as early as 1876. It was not until the early 1940's that sodium borates were found to be effective herbicides on St. Johnswort (*Hypericum perforatum* L.) on the West Coast and on certain deep-rooted perennial weeds in nine midwestern states²⁷ (148). Borates soon came into rather extensive use in some states, mostly in combinations with sodium chlorate (108) and later in combination with more modern herbicides.

A salt of dinitrophenol was used first in France in 1933 (187) for control of annual forbs in cereals. The dinitros

¹⁸ Becker, W. 1840. Probates mittel zur ganzlichen vertilgung des duwocks (*Equisetum palustre*) und (*E. arvense*) Bremen. See Mukula and Ruuttunen (128).

¹⁹ Meyn, L. 1854. Die nachhaltige vertilgung des duwocks. Weimar. 10 p. See Mukula and Ruuttunen (128).

²⁰ Kirchhof, E. 1855. Das Unkraut. 2. Aufl. Leipzig, Reichenbach. 278 p. See Mukula and Ruuttunen (128).

²¹ Bonnet, L. 1896. Le Cuivre contre les ravenelles et les sénéés. Communications dans la séance du Cormice de Reims du 12 Décembre 1896, Soc. Nat. Agr. France. See Mukula and Ruuttunen (128).

²² Hitier, H. 1897. Nouveau procédé de destruction de la moutarde sauvage. J. Agr. Prat. 1:704–706. See Mukula and Ruuttunen (128).

²³ Schultz, G. 1897–1899 a-c. Zur Vertilgung des Ackersenfs und des Hederichs. Landw. Ztg. Westfalen u. Lippe 54:329–330; 55:13–14; 56:1–2, 153–154, 273–275. See Mukula and Ruuttunen (128).

²⁴ Rabate, E. 1911. Destruction des ravenelles par l'acide sulfurique. J. Agr. Prat. 75:407–409.

²⁵ Wunderlich, W. E. 1961. History of waterhyacinth control. U.S. Army Corps Eng., New Orleans Dist. Mimeo Pub. 5 p.

²⁶ Balcom, R. B. 1943. Preliminary survey of the aquatic weed problem in irrigation systems. U.S. Dep. Interior Mimeo Pub. 19 p.

²⁷ Kephart, L. W. 1942. Borax as a weed killer. U.S. Dep. Agr., Bur. Plant Ind. Mimeo Pub. 12 p.

were rather extensively used for annual weed control in onions, peas (*Pisum sativum* L.), and other legumes in many states and in cereals and flax (*Linum usitalissimum* L.) in Canada and northern United States during 1937 to 1945 (15, 43, 86, 88, 110, 153).

Ammonium sulfamate (AMS) has been used for control of woody plants since 1940 (91). Sodium pentachlorophenate received a brief test as a herbicide (93).

Before the discovery of (2,4-dichlorophenoxy)acetic acid (2,4-D), many previously mentioned herbicides had been tested and used with some degree of success for selective control of broadleaf weeds in lawns. These included iron sulfate and ammonium sulfate (167), sodium chlorate (186), kerosene and dinitros (109, 111, 113), sulfuric acid, AMS and gasoline (109).

The development of new herbicides had been progressing steadily since about 1900. However, the discovery of the weed killing properties of the phenoxyacetic herbicides in Britain and the United States during 1942 to 1944 (20, 81, 123) marked the real beginning of the herbicide phase of the "Chemical Era of Agriculture." Peterson (142) presents the complete story of 2,4-D beginning in 1935 with related growth regulating chemicals.

The discoveries and development of the aliphatic acids (52, 58, 117, 162, 192) and derivatives and of the carbanilates (3, 53, 66, 126, 160) occurred soon after those of the phenoxyacetic compounds, and provided supplementary herbicides for the control of weedy grasses. By 1950, the number of herbicides available for public use had increased to about 25 from the 15 available in 1940.

The discoveries of phenoxyethyl sulfate (106), and the phenoxypropionic (23, 47) and the phenoxybutyric acids (180) followed during the early 1950's. The development of improved organic soil sterilizer herbicides progressed rapidly during the 1950's and 1960's with the substituted ureas and uracils (5, 29, 51, 78, 92), the chlorobenzoic acid (23, 51, 80, 147, 189) and phenylacetic acid derivatives (78, 141, 189), the *s*-triazines, triazoles, and other heterocyclic derivatives (23, 49, 52, 78, 98) coming along almost simultaneously. There has been increased emphasis recently on selective herbicides, especially among the carbamates and carbanilates (49, 160), the amine, acetamide, and anilide group, the toluidines and nitriles (49, 52, 181), as well as among the *s*-triazines and substituted urea compounds.

Summary of Herbicide Developments Since 1950

The phenomenal production of new agricultural chemicals, mostly organic compounds, after 1950 and the screening of thousands of these against weeds resulted in approximately 120 herbicides being thoroughly tested and included in the Weed Science list of common and chemical names by 1969. Most of the new herbicides that have been registered and released for public use since about 1950 are listed in Table I chronologically by dates of their first public use in the United States or Canada. These represent about a three-fold increase over the 25 herbicides available for use in 1950. Even more amazing than this rapid increase in number of herbicides now available for public use and about 50 more herbicides being tested was the tremendous increase in use of herbicides. In 1962, as reported by the U. S. Bu-

reau of Census, more than 200 million pounds of herbicides were used to control weeds on about 90 million acres of land at a cost of more than \$200 million. In 1964, the area treated with herbicides was approximately 120 million acres by 1967 total sales of herbicides had increased to 348 million pounds.

The use of herbicides in Canada also increased at a rapid pace. In Alberta, Manitoba, and Saskatchewan, use of phenoxy herbicides increased nearly three-fold from 1954 to 1968.²⁸ The use of other herbicides increased more than eleven-fold between 1963 and 1968.

Developments in Biological Control of Weeds

Along with the rapid progress in development of new herbicides since 1900, there was less spectacular but still very significant progress in biological control of weeds. Holloway (96) gave an extensive review of biological control of weeds by insects through 1964. The earliest attempts at biological control of weeds were in a search for insect pests of lantana (*Lantana camora* L.) in Hawaii in 1902 and in Australia in 1914 (141). In contrast, the first attempt at biological control of a destructive insect pest with parasites had been made about 30 years earlier in 1873 (129). In 1920, the insect *Cactoblastis cactorum* was introduced from Argentina to Australia (55, 120). During 1926 to 1940, that insect performed the amazing and widely publicized feat of practically eliminating 60 million acres of prickly pear cactus (*Opuntia* spp.) in Australia.²⁹ Insects also gave effective control of cactus in South Africa (143) and, to some extent, in the United States (171).

The well-known story of controlling St. Johnswort by the *Chrysolina* beetle began in 1920 with studies of the insect in England. During 1935 to 1944, *Chrysolina* beetles were imported from Britain and France to the United States via Australia (48, 97). After considerable research, distribution of the beetles to weed infestations in California and other states was begun in 1945. Since then, the beetles have made effective inroads on the 400,000 acres of St. Johnswort in California and the Pacific Northwest (96).

Research on biological control of other weeds also included those on gorse (*Ulex europaeus* L.) and tansy ragwort (*Senecio jacobaea* L.) beginning in 1927 (32, 35) and on purple nutsedge (*Cyperus rotundus* L.) beginning in the Philippines in 1922 (194) and in Hawaii in 1925.³⁰ A recent review of projects on biological control of weeds of interest in the United States and Canada were published in 1964 (96) and 1962 (118). Most developments in biological control of aquatic weeds have occurred since 1960³¹ (17, 19, 37, 156, 199, 203).

²⁸ Correspondence from George Friesen, Geigy (Canada) Limited. Toronto, Ontario, Canada. April 1969.

²⁹ Dodd, A. P. 1940. The biological campaign against prickly pear. Commonwealth Prickly Pear Board, Brisbane, Australia. Mimeo Rep. 177 p.

³⁰ Fullaway, D. T. 1954. Fifty years progress in the biological control of weeds—a review. Hawaii Board Agr. and Forestry Mimeo Rep.

³¹ Bennett, Fred D. 1968. Investigations on insects as controlling agents for *Salvinia auriculata* Aubl. and *Eichhornia crassipes* (Mart.) Solms, two weeds of neotropical origin. Commonwealth Inst. Biol. Contr. West Indian Sta., Curepe, Trinidad. Mimeo Rep. 9 p.

Early History of Weed Research

Much of the early research by scientists devoting part time on weeds has been mentioned in discussing early developments in mechanical, chemical, and biological control. Only a few research developments previously referred to incidentally will be repeated in the specific discussion of research developments.

The event which established the basis for outstanding success of agricultural research and eventually of weed research in the United States was the passage by Congress in 1862 of the U.S. Department of Agriculture and Land Grant College Act. Congress appropriated funds in 1878 for research on control of cotton insect pests but did not appropriate funds for weed control research until 1901, 23 years later (12). This research was on control of johnsongrass, which is still one of the nation's most important weeds. The Dominion of Canada initiated weed research in 1889 (77).

According to the early annual reports of state agricultural experiment stations and replies to questionnaires to weed specialists in 50 states and eight Canadian provinces, the first bona fide research on weed control in North America was done by H. L. Bolley at the North Dakota Experiment Station in 1896 (21). During the next 10 years, Professor Bolley conducted rather extensive experiments with copper sulfate, iron sulfate, sodium chloride, sodium arsenite, and corrosive sublimate for control of mustards and other weeds in cereals, flax, and lawns. In the 1908 report (22), he gave an enthusiastic account of the weed research and made the following prophetic statement, "When the farming public has accepted this method (selective chemical weed control) of attacking weeds as a regular farm operation, the gain to the country at large will be greater than that which has been afforded by any other piece of investigation applied to field work in agriculture." However, iron and copper sulfates and the other inorganic herbicides did not work out in large-scale practice. Professor Bolley had the right idea many years before later investigators discovered our modern selective herbicides.

Many state experiment stations began rather extensive research on control of insect and disease pests of crops by the late 1880's and early 1890's using both federal and state funds. However, very few states or Canadian provinces not previously mentioned started weed control research before 1900. Many more began before 1920: Minnesota,³² Ontario (77), North Dakota (183), Maine (197), Iowa (137), South Dakota (132), Rhode Island (1), Ohio, Virginia, and Hawaii,³² Vermont (60), California (18), Nebraska and Massachusetts,³² and Colorado (140).

The first experiments on control of field bindweed by cultivation and competitive cropping were conducted in Kansas in 1907 and 1908. Kansas continued to be a pioneer in research on control of field bindweed with field experiments at the Hays Branch Experiment Station during 1915 to 1930 (31). Extensive research on control of field bindweed also was underway in Nebraska (105) and Utah (164) during this period and in California (43) and South Dakota (63) during 1930 to 1935. Dr. Alden S. Crafts, beginning in 1931 in California, probably was the first scientist to be

employed full time on weed research in the United States.³³ George Knowles, in 1935, became the first scientist to work full time on weed research in Canada.³⁴

In 1935, the Federal Congress appropriated \$40,000 in response to the growing demand for research on control of field bindweed in middle western and western states. This was the first regional weed research project in the United States. Field research stations were located in Kansas, Idaho, Nebraska, Iowa, and Minnesota (168). The first of the five field stations was activated at Hays, Kansas, in July 1935. That is where I started in weed research. The other four stations were initiated early in 1936. Six full-time federal research specialists were employed in this project. Despite its lack of growth in size, the federal-state cooperative weed research project produced some rather outstanding results during the 10-year period 1936 to 1945 (11, 84, 157, 168, 169, 195).

At the time the federal-state research project on field bindweed was initiated, there were not more than 10 or 12 state experiment station workers in the United States who were spending one-tenth to one-third of their time on weed research. The situation with respect to other agricultural pests and agricultural sciences was considerably different. As compared with the handful of full-time and part-time weed research workers, there were more than 500 full-time federal and state experiment station workers in each of the fields of entomology and plant pathology.

The 10 years from 1936 to 1945 were years of slow progress, both for the cooperative field bindweed research project and for weed research in general. During those years, weed research was an orphan activity not recognized as a science. Weed workers were not really considered on a par with research workers in other agricultural sciences. It took considerable courage for a weed worker to admit that he was spending full time, or even part time on that problem. However, we pioneers in weed research took pride in being different and in working for national recognition of the weed problem and of what we considered a budding new science. L. W. Kephart, the widely traveled, well-known, and highly respected leader of the cooperative field bindweed research project, was a crusader for increasing the contribution and prestige of weed control to its rightful place in the nation's economy and among the agricultural sciences (103, 104).

Research in ecological, physiological, and anatomical phases of weed control kept pace with direct control studies. Dr. Beal's buried seed study initiated in 1881 (50) and the similar study begun by Duvell in 1902 (59) were the first of many studies on weed seed viability in soil (25, 36, 72, 172), in feces of animals (85, 134, 170), in silage (202), in water (26, 27), and after various seed treatments (25, 69).

Major investigations of weed root and rhizome depth, distribution and nature and of weed crop competition were begun somewhat later than were studies of seed viability. Minor studies were conducted much earlier in connection with control experiments. Some of the earliest major studies were on roots of perennial weeds, more specifically on field bindweed (106, 169). More comprehensive studies were by

³³ Personal correspondence from A. S. Crafts, Davis, California. April 15, 1969.

³⁴ Personal correspondence from J. R. Hay, Director, Regina Research Station, Regina, Saskatchewan, Canada. September 3, 1969.

³² Information received in correspondence from research workers in these states.

TABLE 1. Chronology of new herbicides since 1950.

Common name	Chemical name	Year of first public use
Monuron	3-(<i>p</i> -chlorophenyl)-1,1-dimethylurea	1952
Endothall	7-oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid	1953
Metham	sodium methylthiocarbamate	1953
MH	1,2-dihydro-3,6-pyridazinedione	1953
Dalapon	2,2-dichloropropionic acid	1954
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea	1954
Silvex	2-(2,4,5-trichlorophenoxy)propionic acid	1954
Amitrole	3-amino- <i>s</i> -triazole	1955
Erbon	2-(2,4,5-trichlorophenoxy)ethyl 2,2-dichloropropionate	1955
Naptalam	<i>N</i> -1-naphthylphthalamic acid	1955
CDA	<i>N,N</i> -diallyl-2-chloroacetamide	1956
Chlorpropham	isopropyl- <i>m</i> -chlorocarbanilate	1956
DSMA	disodium methanearsonate	1956
MonuronTCA	3-(<i>p</i> -chlorophenyl)-1,1-dimethylurea mono (trichloroacetate)	1956
Sesone	2-(2,4-dichlorophenoxy)ethyl sodium sulfate	1956
2,3,6-TBA	2,3,6-trichlorobenzoic acid	1956
CDEC	2-chloroallyl diethylthiocarbamate	1957
Dazomet	tetrahydro-3,5-dimethyl-2 <i>H</i> -1,3,5-thiadiazine-2-thione	1957
EPTC	<i>S</i> -ethyl dipropylthiocarbamate	1957
HCA	1,1,1,3,3,3-hexachloro-2-propanone	1957
Neburon	1-butyl-3-(3,4-dichlorophenyl)-1-methylurea	1957
PBA	chlorinated benzoic acid	1957
Fenuron	1,1-dimethyl-3-phenylurea	1958
Simazine	2-chloro-4,6-bis(ethylamino)- <i>s</i> -triazine	1958
2,4-DB	4-(2,4-dichlorophenoxy) butyric acid	1958
Atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)- <i>s</i> -triazine	1959
DCPA	dimethyl tetrachloroterephthalate	1959
FenuronTCA	1,1-dimethyl-3-phenylurea monotrifluoroacetate	1959
Pebulate	<i>S</i> -propyl butylethylthiocarbamate	1959
Prometone	2,4-bis(isopropylamino)-6-methoxy- <i>s</i> -triazine	1959
Vernolate	<i>S</i> -propyl dipropylthiocarbamate	1959
Acrolein	acrolein	1960
Amiben	3-amino-2,5-dichlorobenzoic acid	1960
Diallate	<i>S</i> -(2,3-dichloroallyl) diisopropylthiocarbamate	1960
Endothall ^a	7-oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid	1960
Fenac	(2,3,6-trichlorophenyl) acetic acid	1960
2,4-DEP	tris[2-(2,4-dichlorophenoxy)ethyl] phosphite	1960
Amitrole-T	3-amino- <i>s</i> -triazole + ammonium thiocyanate	1961
Barban	4-chloro-2-butynyl <i>m</i> -chlorocarbanilate	1961
Cacodylic acid	hydroxydimethylarsine oxide	1961
Propanil	3',4'-dichloropropionanilide	1961
Propazine	2-chloro-4,6-bis(isopropylamino)- <i>s</i> -triazine	1961
Bensulide	<i>O,O</i> -diisopropyl phosphorodithioate <i>S</i> -ester with <i>N</i> -(2-mercaptoethyl) benzenesulfonamide	1962
Dicamba	3,6-dichloro- <i>o</i> -anisic acid	1962
Dichlobenil	2,6-dichlorobenzonitrile	1962
Diquat	6,7-dihydrodipyrido[1,2- <i>a</i> :2',1'- <i>c</i>]pyrazinediium salts	1962
Isocil	5-bromo-3-isopropyl-6-methyluracil	1962
Linuron	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea	1962
Molinate	<i>S</i> -ethyl hexahydro-1 <i>H</i> -azepine-1-carbothioate polychlorodicyclopentadiene isomers	1962
Triallate	<i>S</i> -(2,3,3-trichloroallyl) diisopropylthiocarbamate	1962
Bromacil	5-bromo-3- <i>sec</i> -butyl-6-methyluracil	1963
Butylate	<i>S</i> -ethyl diisobutylthiocarbamate	1963
Diphenamid	<i>N,N</i> -dimethyl-2,2-diphenylacetamide	1963
MSMA	monosodium methanearsonate	1963
Picloram	4-amino-3,5,6-trichloropicolinic acid	1963
Trifluralin	<i>a,a,a</i> -trifluoro-2,6-dinitro- <i>N,N</i> -dipropyl- <i>p</i> -toluidine	1963
Ametryne	2-(ethylamino)-4-(isopropylamino)-6(methylthio)- <i>s</i> -triazine	1964
Cycloate	<i>S</i> -ethyl <i>N</i> -ethylthiocyclohexanecarbamate	1964
Ioxynil	4-hydroxy-3,5-diiodobenzonitrile	1964
Prometryne	2,4-bis(isopropylamino)-6-(methylthio)- <i>s</i> -triazine	1964
Siduron	1-(2-methylcyclohexyl)-3-phenylurea	1964
Bromoxynil	3,5-dibromo-4-hydroxybenzonitrile	1965
Fluometuron	1,1-dimethyl-3-(<i>a,a,a</i> -trifluoro- <i>m</i> -tolyl) urea	1965
Lenacil	3-cyclohexyl-6,7-dihydro-1 <i>H</i> -cyclopenta-pyrimidine-2,4(3 <i>H</i> ,5 <i>H</i>)-dione	1965
Propachlor	2-chloro- <i>N</i> -isopropylacetanilide	1965

TABLE 1. Continued.

Common name	Chemical name	Year of first public use
Pyrazon	5-amino-4-chloro-2-phenyl-3(2 <i>H</i>)-pyridazinone	1965
Benfen	<i>N</i> -butyl- <i>N</i> -ethyl- <i>a,a,a</i> -trifluoro-2,6-dinitro- <i>p</i> -toluidine	1966
Chloroxuron	3-[<i>p</i> -(<i>p</i> -chlorophenoxy)phenyl]-1,1-dimethylurea	1966
Nitrofen	2,4-dichlorophenyl <i>p</i> -nitrophenyl ether	1966
Paraquat	1,1'-dimethyl-4,4'-bipyridinium salts	1966
Terbacil	3- <i>tert</i> -butyl-5-chloro-6-methyluracil	1966
Metobromuron	3-(<i>p</i> -bromophenyl)-1-methoxy-1-methylurea	1967
Nitralin	4-(methylsulfonyl)-2,6-dinitro- <i>N,N</i> -dipropylaniline	1967
Karbutilate	<i>m</i> -(3,3-dimethylureido)phenyl <i>tert</i> -butylcarbamate	1968
Terbutryn	2- <i>tert</i> butylamino-4-ethylamino-6-methylthio- <i>s</i> -triazine	1969

^a For control of aquatic weeds.

Frazier (64, 65) on five perennial weeds and by Pavlychenko and Harrington (139) on annual weeds as affecting competition with crops.

Major studies of organic reserves in roots and rhizomes of perennial weeds were conducted in Kansas and Minnesota in the late 1920's and early 1930's (2, 6, 73). Later studies of root reserves in the 1930's and 1940's were mostly on field bindweed (11, 157, 169, 195). Other early major physiological and anatomical investigations on weeds were conducted about the same time as the early studies of organic food reserves (42, 44).

The discovery of 2,4-D and other phenoxy herbicides in 1942 to 1944 and the resultant publicity provided the stimuli which started weed research on its way as a full fledged new science. Weed research suddenly became popular and all types of scientists—agronomists, botanists, chemists, engineers, physiologists, and economists—jumped into the whirlpool of activity engaged in trying to learn more about this magic new chemical weed killer and about the whole field of new herbicides opened by its discovery. Many chemical manufacturers developed programs of synthesis and screening to discover new herbicides for a broader spectrum of uses and that were more economical or safer. Many thousands of chemicals were screened and many hundreds extensively tested, before the approximately 75 new herbicides could be made available for public use by 1969.

Crafts and Harvey (46) gave a thorough analysis of the status of weed control and research in 1949. Shaw and Lousstalot (161) gave an excellent review of developments and results in weed research, especially during 1950 to 1962. From 1950 to 1962, federal support for weed research increased nearly six-fold for investigations by the Agricultural Research Service and more than 18-fold for research by state agricultural experiment stations. Non-federal funds for state experiment station research were increased 3.3 times. The total increase in all funds for research was from \$800,000 in 1950 to \$4,600,000 in 1962, a 5.7-fold increase.

By 1962, the number of federal and state weed research workers had increased 20-fold to 162 full time on weed research and 238 part time on weed research, equivalent to 84 man-years. This equivalent of 246 full-time weed research workers was still only half the number of public entomologists or the number of plant pathologists engaged in research on control of insects and plant diseases.

Early Legislative and Regulatory Developments

The history of legislative and regulatory developments in weed control more or less paralleled those in weed research. However, enactment of seed and weed laws preceded the initiation of research in many states and provinces. Weeds were involved incidentally in early legislation aimed at control of plant diseases. Fulling (67) gave a comprehensive report on that legislation. Laws requiring eradication or quarantine of barberry (*Berberis vulgaris* L.) as an aid to control of wheat stem rust (*Puccinia graminis* Pers.) were enacted by Connecticut in 1726, Massachusetts in 1755, and Rhode Island in 1766. These early laws were ineffective. However, beginning in 1917, barberry control laws in 13 north central and western states and a federal-state barberry control program proved much more effective.

Currants (*Ribes* spp.), gooseberries (*Ribes* spp.), and other species of *Ribes* were involved in federal and state quarantine and eradication laws aimed at control of white pine blister rust (*Cronartium ribicola* Fisher) which were initiated during 1912 to 1919 in eight New England and 18 other states. In 1914, Virginia passed a law on eradication of red cedar (*Juniperus virginiana* L.) as an aid to the control of apple rust (*Gymnosporangium juniperi-virginiana* Schw.). Arkansas, Nebraska, New York, and West Virginia enacted similar laws during 1919 to 1925.

The first state or province weed law concerned primarily with weed control was in Minnesota in 1872³⁵ and was aimed at Canada thistle (*Cirsium arvense* (L.) Scop.). Ontario (77), North Dakota,³⁵ Texas (12), Montana,³⁵ Alberta, Manitoba, and Saskatchewan (77), California,³⁵ Washington,³⁵ Quebec (77), and Idaho³⁵ were other pioneers in the enactment of weed laws in 1887, 1889, 1895, 1895, 1898, 1903, 1907, 1909, and 1911, respectively.³⁵ The earliest report of enforcement of a weed law found was a fine of \$52 in Manitoba in 1887 (196). The Kansas law of 1937 has been generally considered one of the most inclusive and effective of all state weed laws, including those enacted more recently. Full participation in control of specified weeds by all private and public landowners has been required since 1937 with strong public support and outstanding results (201).

In 1899, the Congress passed the River and Harbor Act

³⁵ Information received in correspondence from extension weed control specialists in these states.

which authorized the U.S. Army Corps of Engineers to develop a program of eradicating water hyacinth in navigation channels in Florida, Louisiana, and other gulf coast states. An amendment of this Act in 1959 greatly expanded the authorization in eight south Atlantic and gulf coast states to include other aquatic weeds and other aquatic sites. In 1967, the authorization to the Corps of Engineers was made national in scope.

The first state seed laws which regulated weed seed content were enacted considerably earlier than weed laws in most states. Connecticut passed a seed law in 1821 that prohibited the sale of forage crop seeds that contained seeds of Canada thistle³⁶ (115). Similar laws were enacted in Ohio, Michigan, and Missouri in 1844, 1871, and 1877, respectively, and in Nebraska and Maine by 1895 and 1897. Other states in which seed laws affecting weed seeds were enacted by 1910 include Iowa, New Hampshire, New York, North Carolina, North Dakota, Tennessee, Utah, Wisconsin, Wyoming, South Carolina, and Virginia.

United States Congressional legislation on weeds has had an interesting history. The National Quarantine Law of 1912 (129) did not cover weed seeds in interstate commerce until it was amended in 1926. The Federal Food, Drug, and Cosmetic Act of 1938 did not apply to herbicides until the Miller Pesticide Residue Amendment was passed in 1954 (129). The Federal Insecticide, Fungicide, and Rodenticide Act of 1947 did include some herbicides but did not cover herbicides for algae and other aquatic weeds until 1961.

The requirements for food tolerances on most herbicides and requirements for registrations of all definitely has reduced the rate of developing new herbicides. The search for herbicides for control of aquatic and bank weeds has been virtually halted. Continued use of several herbicides that have been used extensively for many years may not be permitted.

Education and Extension

Most of the early publications on weeds were of the extension type and provided information on description, distribution of weeds, nature of annoyance or loss caused, and occasionally suggestions on methods of weed control gained from farmer experience. At least four publications of this type were issued by the United States Department of Agriculture during 1860 to 1895 (54, 151, 174, 177), and at least five more were published by 1913 (12, 33, 34, 41). The Canada Department of Agriculture issued at least three information bulletins during 1897 to 1909 (38, 39, 62) and another in 1922 (77).

Early information publications by state and province departments of agriculture during 1887 to 1911, listed in chronological order by date, include Ontario (138), New Jersey (79), West Virginia (121, 122), North Dakota (182), Washington (145), Indiana (7), Kansas (94), Idaho (89), Washington (146), Ontario (87), Vermont (149), North Dakota (179), Vermont (60, 178, 179), Rhode Island (1), California (21), and Idaho (133). Wood (196) presented an excellent history of weeds and their control in Manitoba through about 1958. He stated that stinkweed (*Thlaspi arvense* L.), dandelion (*Taraxacum officinale* Weber), and sow-

thistle (*Sonchus* spp.) were reported to have been introduced in the prairie provinces in bales of trading and foodstuffs as early as 1822. Leafy spurge (*Euphorbia esula* L.) was introduced into Canada from the Ukraine in about 1875.

The weed manual by Scribner (154), published in Maine in 1869, was the first in North America according to the United States Department of Agriculture Annual Report for 1869, page 503. Other early manuals up to 1930 in chronological order by date were by Clark and Fletcher in 1906 and 1909 (38, 39), Pammel in 1915 (136), California Department of Agriculture in 1922 (30), and Georgia in 1927 (70). Apparently, the first complete textbook and manual was published in 1942 by Robbins, Crafts, and Raynor (150).

Two complete reviews of literature on aquatic vascular plants were developed by Arber in 1920 (4) and Sculthorpe in 1967 (155). These are particularly useful to scientists working on aquatic weeds.

In all or most states, the extension agronomists, botanists, horticulturists, agricultural engineers, and other crop specialists began handling education in weed control in their areas of responsibility as soon as the weed problem and information available justified such action. As a Kansas county agent in 1928 to 1929 and extension agronomist in 1935, two of my most important projects were conducting demonstrations and schools on use of weed-free crop seeds and on methods of controlling field bindweed.

Extension weed work was initiated before 1900 in Canada (77). A series of 17 meetings was held in 1899 on control of weeds by tillage and crop competition. Spraying demonstrations with copper sulfate for control of annual weeds in cereals and meetings were held on farms in Ontario in 1901. In 1921, the Canadian Pacific Railroad hauled a demonstration car and two lecture cars on a 6-week tour of 70 locations in Manitoba, Saskatchewan, and Alberta. More than 14,000 people were addressed during this January–February tour.

As nearly as could be determined from correspondence from weed specialists in all of the states, weed extension specialists were first employed full time, or at least half time, in Indiana in 1923, Oregon in 1936, New York in 1940, Delaware in 1942, Nebraska in 1944, Massachusetts in 1945, South Dakota and South Carolina in 1948, Virginia in 1949, California and Rhode Island in 1950, and Washington in 1951. A total of 17 states in the United States were employing 20 full-time weed specialists by 1963. Eighty-nine extension specialists were devoting part time to weed control, equivalent to 18 man-years.

Information on weeds and weed control was presented in botany, crops, and other courses by most agricultural colleges at an early date. However, special courses in weed control were rare until recent years. Some of the first universities to offer special weed courses were Washington in 1915, Montana, Ontario, and Utah in 1922, New Hampshire in 1928, North Dakota in 1931, Oregon in 1936, Kansas in 1938, and California in 1940.

In 1963, Mississippi State University established the Department of Plant Pathology and Weed Science in the Division of Agriculture. This was the first time the word “weed” had been included in the title of an academic department or division. However, many universities give training in weed control in agronomy, botany, and other de-

³⁶ Wallace, Lena B. 1939. Early state laws regulating sale of seeds. U.S. Dep. Agr. Bur. Plant Ind. Mimeo Pub. 6 p.

partments. Some grant M.S. or Ph.D. degrees in weed control research.

Weed Organizations

The Idaho and Utah state weed conferences organized in 1931 probably were the first state weed conferences. Kansas and Wyoming followed suit in 1937, California in 1949, Washington in 1950, Oregon in 1952, Hawaii in 1953, and Montana in 1959.

The Western Weed Control Conference organized at Denver in 1938 was the first regional weed conference in the United States. It was followed by the North Central Weed Control Conference in 1944, the Northeastern Weed Control Conference, Eastern Canadian, and Western Canadian Weed Conferences in 1947, and finally the Southern Weed Conference in 1948. The Northeastern Conference made workers in industry full fledged members and was the first regional conference to do so. The Canadian National Weed Committee was organized at Edmonton, Alberta, in 1929, and has met annually since then with Eastern and Western Conferences or Sections since 1947.

The Canadian Weed Conferences were discontinued after 1959 because of overlapping functions with the National Weed Committee. Since then they have met separately as Eastern and Western Sections of the National Weed Committee.

The Association of Regional Weed Control Conferences was organized in 1949. It initiated the first scientific periodical—*Weeds*—in 1951 and sponsored the first joint weed meeting at Kansas City, Missouri, in 1953. The Weed Society of America was organized at Fargo, North Dakota, in 1954 and held its first meeting at New York City in 1956. The Society, now the Weed Science Society of America, adopted *Weeds*, now *Weed Science*, as its official journal. This was about 50 years after organization of entomological and phytopathological societies. Manufacturers of herbicides, of application equipment, and other members of industry gave strong support to the regional conferences and the American Society. Dr. R. H. Beatty, a representative of industry, served as the first President of the Weed Society of America. Many other representatives of industry were active in the affairs of the Society and of the regional conferences and state weed organizations.

Weeds was published during 1951–1954 as a trial venture. Publication was resumed in 1956 as the official journal of the Weed Society. Dr. R. D. Sweet, Dr. C. E. Minarik, and Dr. W. C. Shaw were Editors during 1951 to 1954. Dr. K. P. Buchholtz served as Editor of the official journal during 1956 to 1958, and as President of the Society in 1960 to 1961. In 1964, the Society began electing members to Honorary Membership. The members selected that year were A. S. Crafts, K. P. Buchholtz, F. L. Timmons, and C. J. Willard.

A significant boost for weed control as a science before the formation of our American Society was the Presidential address of C. J. Willard on “Weed Control: Past, Present, Prospects” (193) presented at the American Society of Agronomy meeting in November 1954. Dr. Willard later served as Editor of *Weeds* for 7 years immediately preceding our present Editor, Dr. E. G. Rodgers, who has served since 1965. The name of the journal was changed from *Weeds* to *Weed Science* in January 1968.

During the short period since 1956, the science of weed control has become of age and has begun to fulfill its destined role in the progress of agriculture and national welfare. The most potent factor has been the impact of the Weed Society, now Weed Science Society of America, through the *Weeds* journal, now *Weed Science*, and the activities of the Terminology, Education, Public Relations, and other committees.

Most phases of the history of weed control to 1969 have been considered. A perspective of the chronology and the relative time lapse of the significant eras or periods in the history of weed control is shown in Table 2. After the beginning of stabilized agriculture in about 6000 B.C., about 7,800 years were required for man to progress from the Y-shaped tree limb, which we have called a hoe, and the T-shaped tree limb pulled by cattle or slaves, to the invention of the early plow, the horse hoe, and the wheel cultivator. Some writers during 1550 to 1800 A.D. recognized weeds as a problem.

The period 1801 to 1900 marked the beginning of the mechanical and horse-power era in agriculture. Inventions and improvements in metal implements and tools came along at a rapid pace, at least by 19th century standards. Man began to experiment with a few inorganic chemicals for weed control. The progress in agriculture and in weed control in that century was much greater than man's progress during the previous 78 centuries of stabilized agriculture.

During the 40-year period from 1901 to 1940, the tempo of improvements in equipment for mechanical weed control increased rapidly and several new herbicides were discovered and came into wide use. That period saw the transition from horse-power to gasoline-power farming, a tremendous increase in the amount of cultivated land, especially in the West and Middle West, and a many-fold increase in the use of mechanical and chemical weed control. The 1920's and 1930's were glamorous and romantic years for entomologists, plant pathologists, plant breeders, soil fertility specialists, soil conservationists, and scientists of almost every discipline. They were basking in a halo of achievement and public acclaim. However, those were hard years for the handful of weed scientists.

During the 28 years after 1940, especially after the discovery of the phenoxy herbicides, the number of man-years in weed research increased 20-fold. The number of man-years in weed extension work increased 19-fold. The number of state, regional, and national conferences increased from three to more than 40 in the United States and Canada. The number of registered approved herbicides available for public use increased about six-fold, and the acreage on which chemical weed control was practiced increased many hundred fold.

In Table 2 it can be seen that this 28-year period represents only 0.35% of the 7,970 years since stabilized agriculture began. The progress of agriculture and weed control during each successive period on the chart was greater than in all previous periods combined. It is difficult to imagine how that rate of progress can be maintained in the future. However, I remember having a similar thought in 1940; therefore, perhaps the history of weed control is just beginning.

A frequently quoted statement in recent years is that 95%

TABLE 2. Chronological perspective of progress in the art and science of weed control.

Period of years	Percent of time	Percent of progress ^a	Significant events
6000 B.C. to 1800 A.D	97.9	1	Hand implements, wood, later with metal points or blades. Cattle drawn implements, wood and metal plows, wheel hoe. Early publications on nature of weeds and problems and damages caused.
1801 to 1900	1.25	4	Improved plows, wheel cultivators, mowers, disks, drags of "horsepower era." Early hand and horse-drawn sprayers. Early seed and weed laws. Early use of and research with inorganic herbicides. Increase in publications on nature and distribution of weeds, problems caused and methods of control. Weed control proved chief advantage of cultivating row crops.
1901 to 1940	0.50	15	Transition from horse-power to gasoline tractor-power implements. Improved blade, shovel, and rod weeders and tractor-mounted sprayers. Gasoline-powered aquatic weed crusher and saw-boats, chains, and drags. Increased research with inorganic herbicides and cultivation methods. First full-time extension and research weed workers. Fifteen herbicides available for public use.
1941 to 1968	0.35	80	Discovery of phenoxyacetic herbicides. Beginning of "chemical era" of weed control. Number of herbicides available for public use increased from 15 to 100 with emphasis on selective weed control in crops. Rapid increase in research and extension manpower. Organization of state and regional weed conferences and of Weed Society of America. Weed control officially named a science.

^a Author's estimates of relative amounts of total progress.

of the scientists who ever lived are still alive.³⁷ If that is true of scientists in general, it certainly is even more true in the science of weed control, which got started late. It is an exhilarating yet humbling feeling for one whose scientific career began in 1928 to realize that 95% or more of the progress of mankind in his field has occurred during his lifetime. However, as an old timer in modern weed science, I want to emphasize the importance of the early struggles and progress in the art and science of weed control. The battles we fought and the victories we won before 1950, before 1940 and 1930, and which the real old timers experienced before 1920, were necessary stepping stones to the phenomenal advance of weed science in the most recent 20 or 25 years. The young science of weed control has a glorious heritage. We can be confident that the younger and future workers in the art and science of weed control will fulfill the promise of that heritage.

Acknowledgments

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