History of Soil Fertility Research at Washington State University[1]

F. E. Koehler[2]

The ability of the soils of Washington to provide nutrients to crop plants has been of concern to researchers at Washington State University since its establishment in 1892. Problems were initially addressed by chemists and agronomists since it was many years before soil fertility specialists were acquired.

The earliest report concerning soil fertility in Washington was published by Fulmer and Fletcher (1894). They analyzed soils chemically and predicted nutrient needs. Considering the knowledge available on soil fertility and plant nutrition of that time, they made some excellent contributions about the nature of Washington soils. They stated that "western Washington soils will be greatly strengthened by application of lime", "the average percent of lime and potash are higher, phosphoric acid lower in eastern Washington soils than in western Washington soils", and "lime percent is lower in regions of abundant rainfall than in drier portions of the state". They also said that "chemical analysis can reveal deficiences in plant food and give percentage composition but cannot show availability". At that time there were total chemical analyses of soil, but it was much later before the concept of analyzing soils for "available nutrients" developed.

Later Fulmer and Heileman (1899) published a bulletin on the principles underlying the use of fertilizers and sources and composition of fertilizers.

---

[1] Part of History of Agronomy and Soils, WSU, 1986

[2] Soil Scientist and Professor of Soils, Department of Agronomy and Soils, Washington State University, Pullman, WA 99164-6420

They considered the critical elements to be nitrogen, potash, phosphoric acid, and lime. They wrote "These four elements of plant food are the only ones that need concern us; not because the others are so unimportant, but because they are always present in soil in sufficient quantity for the needs of the plant for all time". They said that there were two kinds of fertilizers: direct and indirect. To them potash, nitrogen and phosphoric acid were direct fertilizers. They stated further, "Indirect fertilizers do not of themselves furnish plant food, but they serve to render more available the food already present in the soil. The most common indirect fertilizers are gypsum (land plaster) and common lime". Again, this reflected the knowledge and the thinking of that time.

Only ten years later Thatcher (1909) stated that "lime as a fertilizer may act directly as a plant food or indirectly by rendering other plant food more available". At that same time personnel of the Washington Agricultural Experiment Station undertook to determine whether or not Washington soils were deficient in sulfur. Some results of these studies were later published (Olson and St. John, 1921) showing that at Pullman in 1912 yields of alfalfa were almost doubled by the use of gypsum and on farmers fields the yield of alfalfa was increased 290% by the addition of 200 lbs. gypsum per acre. Thus sulfur was soon established as one of the "critical elements" in these Palouse soils.

About that same time Schafer et al. (1921) reported that the yield of annual cropped winter wheat was increased from 18.7 to 32.9 bu/A by the use of barnyard manure. Yield of winter wheat was much higher in a summer fallow system. Sievers and Holtz (1922) found that just 39 years of a winter wheat-summer fallow cropping system resulted in the loss of 22% of the total nitrogen in the topsoil of an eastern Washington soil. This suggested that

the nitrogen mineralized during the summer fallow season was responsible for the increased yield of the following winter wheat crop. Sievers and Holtz (1924) later reported a 10 bu/A increase in wheat yield from the addition of 100 lbs. sodium nitrate/A and stated that in the higher rainfall area the first limiting factor for wheat yield under annual cropping was nitrogen rather than water.

These early works were the beginning of a greatly expanded soil fertility research program, with programs for various regions of the state being centered at different research installations. Researchers stationed at Puyallup and Mt. Vernon were responsible for the work west of the Cascades, those at Prosser for irrigated agriculture in the central part of the state, those at Wenatchee for soil fertility research on tree fruits, and those at Pullman for the dryland agriculture of eastern Washington. These regions will be discussed separately in the remainder of this chapter.

EASTERN WASHINGTON DRYLAND AREA, PULLMAN

Various members of the soils faculty were assigned responsibility for soil fertility research before full-time soil fertility researchers were employed. Among these were H. W. Smith who published a very informative circular on nitrogen fertilization of wheat (Smith, 1950) based on his work and that of many others. At the same time Horner and Vandecaveye (1950) published the results of numerous experiments on nitrogen fertilization of wheat carried out with the assistance of J. L. Haddock, Glenn Langley, V. G. Kaiser and Walter Guenther.

In the late 1940's, Harley Jacquot, who had formerly been superintendent of the Lind Experiment Station, did numerous experiments on the use of N fertilizers on wheat, especially in the intermediate rainfall (14-18 in.) area of the region. His work (Jacquot, 1953) and that of Tom Jackson laid the

groundwork for the research of Glen Leggett who refined the idea of calculating wheat yield potentials on the basis of available soil moisture plus estimated additional moisture from normal rainfall and determining the amount of N required to reach that yield. Then recommendations for N fertilization could be based on the difference between the N required and that available (Leggett, 1959). Leggett's formulae have since been revised based on the work of F. E. Koehler and is used as a guide for fertilizer recommendations by SCS and Extension personnel (Engle et al., 1975). Thus we see a fascinating history of N fertilizer use for wheat in eastern Washington -- from none in the early years to about 100 lbs N/A in the Palouse region at present. This is the result of an accelerated rate of organic matter decomposition and consequent loss of N, removal of organic matter-rich topsoil by erosion, and the higher requirement for N resulting from improved varieties and improvements in production techniques.

Meanwhile the need for addition of other nutrient elements for eastern Washington crops had been discovered. As mentioned before, the need for sulfur fertilizer for alfalfa was reported in 1921. Mike Reisenauer and Glen Leggett (1957) found that sulfur fertilizer was also required for peas and for wheat. Later work by Roberts and Koehler emphasized the widespread nature of the sulfur deficiency and showed that many materials could be used as fertilizers to supply the sulfur needed by plants. Reisenauer (1957) also determined that molybdenum had to be added for legumes -- peas, lentils, and alfalfa. His first recommendation was for about 2 lb. of sodium or ammonium molybdate per acre, but he then discovered that seed treatment of large seeded legumes was so much more efficient that an ounce per acre on the seed would suffice.

In the late 1950's and early 1960's, Fred Koehler and co-workers showed

that phosphorus was extremely deficient on eroded hilltops and on "clay knobs" whose exposure was such that no recent loess had been deposited on them (Guettinger and Koehler, 1967). Following a couple of years of small plot research, Koehler in cooperation with the Northwest Plant Food Association and county extension personnel, established a series of "strip" demonstrations where phosphorus fertilizer was applied in strips beginning in low-lying areas and going up the slope and over hilltops. The response was extremely dramatic. These demonstrations were used by Extension workers for field tours for growers and fertilizer industry personnel. This, and the dissemination of yield data (yields were often increased 300% or more) soon made the use of phosphorus fertilizer on deficient areas so widespread that it was difficult to find research sites where a response could be obtained. The only other nutrient found to be deficient throughout much of the eastern Washington dryland farming region is boron for legumes. In the past, this has been supplied largely as borated gypsum.

With the increased recognition of the seriousness of the erosion problem in eastern Washington and the increased emphasis on erosion control research through the STEEP (Solutions to Economic and Environmental Problems) program considerable effort was made in the late 1970's and early 1980's to determine fertility requirements of wheat grown with conservation tillage systems, especially no-till. The other major thrust in fertility research during this period was to determine fertility practices required for maximum yield.

In 1962 Dr. Reisenauer left Washington to take a position at The University of California at Davis and was not replaced. In 1960 Dr. R. L. Hausenbuiller was transferred from Prosser to Pullman, primarily to teach the basic courses in soils with a minimal research appointment to work at soil fertility research. After Dr. Hausenbuiller's retirement in 1983, the

teaching duties in soils were realigned and Dr. W. L. Pan was hired in 1984 with a 30% teaching appointment and 70% of his time to be devoted to soil fertility and plant nutrition research. The use of graduate students in soil fertility research has greatly increased over the last twenty years (1966 to 1986).

TREE FRUIT RESEARCH CENTER, WENATCHEE

Early in the 20th century orchardists in the Wenatchee area began having trouble growing new apple trees (resets) in old orchard soils, even though they used nearby topsoil as a growth medium. By the late 1920's or early 1930's most resets died. Then extension Horticulturist John Snyder discovered that if trees were planted in no-orchard soils, they survived. Soon after this, Earl Blodget and Bob Lindner discovered that arsenate sprays were toxic to fruit trees; so one of the causes of the "reset" problem was identified.

In 1946 the first soil scientist, Dr. Nels Benson, was assigned to the Wenatchee Station. Later he was on a split appointment, 50% in Soils and 50% in Horticulture. Dr. Benson demonstrated that this "new soil technique" of planting in no-orchard soils was an avoidance of the toxic arsenic. Since all aspects of management for establishment of new trees must be optimum, Dr. Benson cooperated with other scientists in studies on weed control (Benson and Degman, 1961), water management (Hintz and Benson, 1946), and management of orchard cover crops (Overley and Benson, 1946).

Another aspect of the apple replant problem receiving considerable attention was that of soil pests. During the life of an orchard there was a buildup of nematodes, injurious microbes, etc. which could be eliminated by proper fumigation (Benson et al., 1978).

Another soil problem discovered by Benson early in his career at Wenatchee was that of soil acidity (Benson, 1949). This had resulted from the

extensive use of ammonium sulfate as a source of nitrogen on the relatively coarse textured soils with low exchange capacity. The shift to other sources of nitrogen led to another serious problem, sulfur deficiency, in orchard areas dependent for irrigation on the low sulfur waters of streams flowing out of the eastern slope of the Cascades. Another problem caused by the soil acidification was that of manganese toxicity (Benson et al., 1972). This could be cured by liming the soil.

Dr. Benson did research on and found solutions to numerous other soil related problems. Iron deficiency was one of these largely brought on by the use of irrigation water high in bicarbonate or by high pH soils. The iron deficiency could be cured by the use of iron chelates (Benson, 1961). Another problem was zinc deficiency (Benson et al., 1957) and another, boron deficiency (Benson and Bullock, 1948). Copper deficiency in some areas was yet another nutritional problem diagnosed in some areas and solved by Benson.

Three other important areas of research by Dr. Benson were the use of nutrient sprays (Benson and Bullock, 1951); the identification of fluoride toxicity of peaches (Benson, 1958) which resulted from hydrogen fluoride emissions from an aluminum processing plant near Wenatchee; and cooperation in the study of pear decline.

Dr. Benson retired in 1977 and was replaced by Dr. Burt Koch who did largely physiology research from 1977 to 1984. The Soil Scientist-Horticulturist position has recently been filled with Dr. Frank Peryea who has a very vigorous research program underway.

IRRIGATED AGRICULTURE RESEARCH AND EXTENSION CENTER, PROSSER

The "Irrigation Experiment Station" was created by a bill passed by the Washington legislature in 1917. A site was selected and purchased and although the first funds for development and operation were not available

until 1919, a large volunteer crew of over 100 people turned out on May 18, 1918 and again on April 13, 1919 to clear and prepare the land for irrigation. The first water was delivered on May 24, 1919 and crop production began that year.

Harold Singleton was appointed Assistant in Farm Crops in October 1920 and transferred to the Irrigation Experiment Station in May 1921 to start research programs in crops and soils. One of his duties was to conduct fertilizer trials on many crops. He took many plant and soil samples and each winter through 1928 he spent one-and-a-half to two months in Pullman analyzing these samples under the direction of Henry Holtz. Upon the death of Superintendent Roy Bean in 1929, Mr. Sngleton was appointed Acting Superintendent and later Superintendent, in addition to his research duties in crops and soils.

In 1937 the Vocational Agriculture Instructor at Prosser, C. Emil Nelson was awarded a two-year fellowship to obtain a Master's Degree at Washington State College and in 1939 he was appointed Assistant Agronomist. Dr. Carl Larson of the USDA did soils research at the Station from 1931 to 1942 and upon his departure, Emil Nelson resigned his state position and was appointed by the USDA to continue Larson's work. Emil Nelson continued his duties in applied agronomic research at Prosser until his retirement in 1972. He was a most productive researcher and was probably the last "real agronomist" who covered all aspects of production including rate, date and placement of fertilizer; kinds of fertilizer; type and variety of crops; seeding methods, dates, and rates; etc. Dr. C. O Stanberry assumed Nelson's state duties in 1942 and continued until 1951 when he moved to Arizona because of his health.

Dr. R. L. Hausenbuiller replaced Stanberry in 1951 and did soil fertility research there until 1960 when he moved to Pullman to concentrate mainly on

teaching beginning level soils courses.

In 1945 Washington State University and U. S. Department of Agriculture personnel met to plan for research needed to solve agricultural production problems for the upcoming Columbia Basin Irrigation Project. U. S. D. A. personnel involved with soil fertility research included Emil Nelson who was already at Prosser; Sterling Olson, soil chemist; Frank Viets, agronomist; and Clifford Domingo, agronomist. These researchers made some outstanding contributions on soil fertility problems, solutions for which were needed for maximum efficiency of production in the newly irrigated acres as well as in the older established irrigation districts. One of the most notable of these was the identification of and cure for, zinc deficiency. Leader in this was Dr. Frank Viets who was joined by Louis C. Boawn in 1953. When Viets moved to Ft. Collins, CO in 1954 he was succeeded by Dr. Jack Nelson who continued the zinc work and other projects. Nelson left in 1957 and was followed by Dr. Glen Leggett who was transferred to Kimberly, ID in 1965. Boawn engaged in cooperative work with these scientists and continued the zinc work until his retirement in 1976. Dr. David Lauer came to Prosser in 1977 and continues his research with phosphorus, nitrogen and other aspects of soil fertility.

Following the establishment of a central soil testing laboratory at Pullman, a program of "Outlying Testing" was initiated by Dr. C. B. Harston, extension soils specialist, to gather soil test correlation and calibration data. This proved to be a great opportunity for developing the soil testing program, but the task was too large for one individual to handle so Outlying Testing Specialists were hired for eastern, central and western Washington. Harold Cosper took over the program at Prosser in 1953 but stayed only until 1955 and was succeeded that year by A. Irving Dow who combined applied research with extension soil fertility activities for an outstanding service

to irrigated agricultural producers until his retirement in 1983.

Meanwhile research in soil fertility by other state workers was continued first by Dr. Arvil Hunter and then by Dr. David James (1962-1969). Dr. James made outstanding contributions in phosphorus and potassium research as well as in other aspects of soil fertility.

Steve Roberts joined Emil Nelson in 1957 upon completion of his M.S. degree at the University of Nebraska. He later moved to Pullman to complete his Ph.D. degree in soil fertility and after a short stay at Oregon State University, returned to Prosser to lead the soil fertility research there. Noteworthy contributions have been made by him in fertility relationships in the production of potatoes, wheat, and corn. He has served on the advisory committee of numerous graduate students in soils and actively cooperates in their thesis research projects.

WESTERN WASHINGTON RESEARCH AND EXTENSION CENTER, PUYALLUP

The 1891 law which established the "State Agricultual College, Experiment Station and School of Science" required that a "sub-station" be established west of the Cascades. Some land was given and some sold to the institution and on July 1, 1895 a Station Superintendent was appointed for the "Ross Station" at Puyallup. However, the USDA ruled that Hatch funds could not be used at branch stations and since there was no appropriated state money, the station was closed in 1897. The station reopened in 1907. It later became the Western Washington Experiment Station and operated independently of the Pullman Station until 1943.

The first agronomist at the station, M. E. McCollam, was appointed in 1920. He did a number of studies on the use of manure and commercial fertilizers on various crops and on pastures. He even compared potassium chloride with potassium sulfate on muck soils of the area.

McCollam resigned in 1928 and was replaced by Maynard Grunder who continued soil fertility research as well as other agronomic research. However, the amount of research in soil fertility remained relatively minor until the hiring of Karl E. Baur in 1944 and shortly thereafter adding Todd Tremblay. These two scientists had a very large program covering much of western Washington. Major emphasis was on types, rates, and placement of fertilizer on many crops. They also did considerable work on the use of micronutrients.

Another subject of research introduced by Baur and Tremblay was the use of plant analysis. They did extensive plant tissue testing and total plant analysis as indicators of soil fertility. Part of this research was in conjunction with researchers in Pullman. For example Vandecaveye and Tremblay (1945) published on the effect of liming and fertilizer treatments on the growth and composition of spinach.

Baur left in 1951 to work in the fertilizer industry and was a major supporter of cooperation between the industry and researchers for many years. Tremblay also left to work in the fertilizer industry and joined the National Plant Food Institute in 1958. He, too, promoted soil fertility research and served a liaison function between industry and research.

Harry Kittams did soil fertility research in western Washington from 1952 to 1956 and was joined by Dr. Walter Mortenson in 1953. Mortenson had an extensive program especially on small fruits and vegetables and remained at Puyallup until 1976.

The "Outlying Testing" program for western Washington was begun by Dr. Lowell Nelson in 1954 to obtain data for correlation and calibration of soil tests. Nelson moved to Pullman in 1956 to become the first full-time director of the State Soil Testing Laboratory, and D. O. Turner, a county extension

agent in the area, was appointed to replace him. Turner served in this position and as Extension Soils Specialist until his retirement in 1981. He made many significant contributions to research and extension during his tenure.

Dr. Aaron Baker joined the soil fertility research group at Puyallup in 1958 and while his program included a major effort in the soil chemistry aspects of soil fertility he had a considerable field program, especially in the need for boron in the area.

Dr. Shiou Kuo came to Puyallup in 1978 to do soil chemistry and soil fertility research. He has a very active program in soil phosphorus research and in reactions of heavy metals in soils with both field and laboratory studies in each area.

Dr. Baker retired in 1982 and was not replaced. Turner retired in 1981 and no one was hired to assume his soil fertility duties. Therefore, there is now a greatly diminished program of soil fertility research and extension in western Washington.

The use of lime on western Washington soils has been studied from the beginning of agricultural research in this state until the present time. Fulmer and Fletcher (1894) discussed this in their earliest bulletin. Both McCollam and Grunder conducted studies on liming, as did Baur and Tremblay. Methods of determining lime requirements were studied by many researchers, both at Puyallup and at Pullman. L. E. Dunn of Pullman used titration curves and also studied the effects of lime on availability of other plant nutrients. D. O. Turner who became "Outlying Testing Specialist" in 1960 developed a method in cooperation with A. R. Halvorson of the Soil Testing Laboratory in Pullman which was based on percent base saturation. This method was used extensively until the State Soil Testing Laboratory was discontinued in 1983.

Aaron Baker devoted much time to this subject and developed a double buffer method which worked quite well but was very complicated to run. He later published a simplified method for determining lime requirements (Baker and Chae, 1977).

GENERAL STATEWIDE SOIL FERTILITY ACTIVITIES

There were two general statewide activities of soil fertility researchers which contributed substantially to the success of the research program in the state and to the excellent relationship between Washington State University and the fertilizer industry. The first of these was the annual State Soil Fertility Workers Conference which was begun in the early 1950's. Meetings were held at the various research stations in the state so workers became acquainted with facilities and local conditions as well as with programs and personnel. Frank discussions of problems and sharing of ideas on how to attack them resulted in better planned experimental approaches. Unfortunately financial conditions made it impossible to continue these conferences every year and finally in the early 1970's they were discontinued altogether.

The second activity was the cooperation of the Washington State University faculty with the Northwest Plant Food Association (NWPFA) which was organized in 1949. The prime mover in this development was Dr. B. R. Bertramson, Chairman of the WSU Agronomy and Soils Department, who saw the need for a cooperative effort between state and federal researchers and the fertilizer industry. The primary functions of the NWPFA was to sponsor, through its Soil Improvement Committee, a summer conference and to support applied soil fertility research.

At the summer meetings researchers from state, federal, and industry organizations presented results of their soil fertility and related studies. The presentations were published in a proceedings each year so they were

widely available to industry personnel. Approximately one-fourth of the 750 papers published through 1985 were written by Washington personnel, with a total of 93 Washingtonians on the author list.

Soil fertility is a major factor in the efficient production of high yielding crops. The state of Washington has been very fortunate to have an excellent group of dedicated researchers to work on soil fertility problems. The application of their results in agricultural production has repaid the cost of the research many times over.

REFERENCES

1. Baker, A. S. and Y. M Chae. 1977. A laboratory quick test for predicting the lime requirement of acid mineral soils. Tech. Bul. 88. College of Agriculture Research Center, Washington State University.
2. Engle, C. F., F. E. Koehler, K. J. Morrison and A. R. Halvorson. 1975. Dry land wheat nitrogen needs. Fertilizer Guide 34. Cooperative Extension Service, Washington State University.
3. Fulmer, Elton and C. C. Fletcher. 1894. Washington soils. Agric. Exp. Sta. Bul. 13. State College of Washington.
4. Fulmer, Elton and W. H. Heileman. 1899. Fertilizers. Part I. Principles underlying the use of fertilizers. Part II. Sources and compositions of fertilizers. Agric. Exp. Sta. Bul. 40. State College of Washington.
5. Guettinger, D. L. and F. E. Koehler. 1967. Phosphorous increases wheat yield. Extension Minneo. 2840. Washington State University.
6. Horner, G. M. and S. C. Vandecaveye. 1950. Nitrogen fertilizer for wheat, eastern Washington. Agric. Exp. Sta. Circular 86. State College of Washington.
7. Leggett, G. E. 1959. Relationships between wheat yield, available moisture and available nitrogen in eastern Washington dryland areas. Agric. Exp. Sta. Bul. 609. Washington State University.
8. Olson, G. A. and J. L. St.John. 1921. An investigation of sulfur as a plant food. Agric. Exp. Sta. Bul. 165. State College of Washington.
9. Reisenauer, H. M. 1957. Molybdenum for legumes in eastern Washington. Agric. Exp. Sta. Circular 307. Washington State University.
10. Reisenauer, H. M. and G. E. Leggett. 1957. Eastern Washington soils need sulfur. Agric. Exp. Sta. Circular 317. Washington State University.

11. Schafer, E. G., E. F. Gaines and O. E. Barbee. 1921. Cultural experiments with wheat. Agric. Exp. Sta. Bul. 160. State College of Washington.

12. Sievers, F. J. and H. F. Holtz. 1922. The silt loam soils of eastern Washington and their management. Agric. Exp. Sta. Bul. 166. State College of Washington.

13. Smith, H. W. 1950. Nitrogen fertilizers for wheat production. Agric. Exp. Sta. Circular 85. State College of Washington.

14. Thatcher, R. W. and Bryon Hunter. 1909. Part I. Lime as a fertilizer. Part II. Farm practices in applying land plaster in western Oregon and western Washington. Agric. Exp. Sta. Bul. 88. State College of Washington.

15. Vandecaveye, S. C. and F. T. Tremblay. 1945. The effect of limestone and fertilizer treatments upon the growth and composition of spinach. Soil Sci. Soc. Am. Proc. 9:169-179.