



Katherine Esau in front of the Botany Building at UC Davis. Davis, 1958.

KATHERINE ESAU, 1898–1997

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I was born on April 3, 1898, in the city of Ekaterinoslav, now called Onepetrovsk. The city was named originally after the Zarin Katherine the Great who promoted agriculture in the steppes of the Ukraine by inviting settlers from Germany, among them the Mennonites. My family are Mennonites.

Russia

Katherine Esau entered a Mennonite Parish school in Russia in 1905, at the age of 7. In 1909, she entered the gymnasium, a secondary school that prepared students for careers in teaching or for entrance to college. An excellent student, Ms Esau was always at the top of her class. Upon graduating in 1916, she received a gold medal for her accomplishments. With outstanding grades and a love of learning, Ms Esau applied to and was accepted at the Golitsin Women's Agricultural College in Moscow in 1916. She began her studies with courses in natural sciences, physics, chemistry, and geology. She chose to study agricultural sciences because she liked working with plants; moreover, agriculture appeared to deal with plants in a more interesting way than botany, which seemed to her to deal mainly with the naming of them.

During her first year of college, the Moscow authorities called on students to do their part for the country. Ms Esau was responsible for supervising an area in Moscow. She patrolled the streets at night, but eventually it became too dangerous for her to continue this task alone.

At the end of the second semester (1917), the Revolution interrupted her schooling so she returned to her parents home in Ekaterinoslav. There she had private English lessons, took piano lessons, attended a local gardening school, and with a friend from college, collected plants for a school project.

The Russian Revolution affected the Esau family in part because of their German ancestry and because of their wealth. John Esau, her father, had been the mayor of Ekaterinoslav, but the Bolsheviks forced him to resign. When the

Germans occupied the Ukraine, John Esau was reinstated as mayor. With the defeat of the Germans by the Western allies, it became very dangerous for the Esau family. John Esau, along with his wife and daughter, left Russia on a German troop train. Paul Esau, her brother, was serving as an administrator on a ship in the Black Sea so was unable to depart with the family. He was able to leave, however, soon after his family left. The Esaus had little time to prepare. They managed to sell their house just before departing, providing them with some money. Katherine and her mother packed family treasures and photo albums in a large wooden case in the attic. They never were able to reclaim those items; however, Dr. Esau kept the key to the attic until her death. The saddest memory of leaving Russia was watching her cat, Murka, in the upstairs window of their home as they drove away to meet the German troop train.

The Esaus departed Ekaterinoslav on December 20, 1918, and arrived in Berlin on January 5, 1919. The day after they left, posters appeared in Ekaterinoslav proclaiming that the new city managers were looking for John Esau, evidently to take care of this representative of the old regime. John Esau belonged to the "counterrevolutionary bourgeoisie" and was considered an enemy of the country.

The Esaus traveled for two weeks in a third-class carriage of a German troop train. This carriage had only wooden benches for seats. The injured soldiers and German officers also rode in this section. It was a difficult two-week trip. There was little food, cold temperatures, crowded cars, and the fear of not being able to get through to Germany.

My first thought, after arriving in Germany, was that I should find a school where I would want to study. I think they were just beginning the spring semester. I had my Russian documents with me and I went to an agricultural school. They accepted me without question. So I became a student. At that time, Berlin was still a combat zone. Government forces were fighting the communists in the streets and it became difficult even to get to school. We found a good place to live, but it was far from school, so I had to walk a long distance until they finally got the local trains running again.

Germany

The Esaus stayed in a hotel in Berlin until they found more suitable accommodations. Ms Esau registered in the Berlin Landwirtschaftliche Hochschule. She adjusted quickly to the German language and developed a close relationship with Dr. Aeroboe, who taught a general course on farm management, and with Professor Erwin Bauer, a geneticist who became famous for his studies in plant breeding. Ms Esau spent three years at the college. The instruction consisted of lectures and practical experience. It was customary for the students to work on farms in the summertime. One summer was spent on a farm in Hohenheim and another on an estate in Saxony near Leipzig. Her duties at Hohenheim included milking the cows and weighing the newly born piglets. In Saxony, she assisted the owner, Herr Kirsche-Pfiffeldorf, with potato breeding.



Figure 1 Top left: Katherine Esau with Murka on her lap and Mars sitting at her feet, Ekaterinoslav, 1910; bottom left: portrait of Katherine Esau, Berlin, 1919; right: Katherine Esau at the UC Berkeley commencement, Berkeley, 1932.

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**SUGAR BEET BREEDING
 RECEIVES AN IMPETUS**

Breeding of sugar beets to resist curly top, being carried on at the University Farm, Davis, received an impetus recently when the breeding experiment which has been conducted by the Spreckles Sugar Company at Spreckles for nine years was given to the University of California and the stock transferred to Davis.

With the experiment, Miss Katherine Esau, trained in Germany, came to the Branch of the College of Agriculture at Davis to carry on the experiment, which will be run with those already under way by the College here.

According to Dr. W. W. Robbins of the Botany Division, one strain, known as P-19, has proved resistant to a promising degree, and work with it will be continued.

Work in breeding beets for resistance to curly top was begun at Davis two years ago, in response to a demand from the beet growers of the State, whose crops had been badly damaged that year by curly top. In addition to the breeding work, search for a parasite that may control the leaf hopper that carries the disease organism also is under way, and a study of the organism itself is being carried on.



Figure 2 Left: article from the Davis newspaper on Katherine Esau's sugar beet research, Davis, 1928; right: Katherine Esau at Spreckles, Ranch 11, King City, California, 1925.

We left for America in the middle of October 1922 without my brother Paul, who needed another year at the University. He was studying oil chemistry. We crossed the ocean by boat and the continent by train. We were checked in at Ellis Island where, among other things, they tested our ability to read. I could read English at that time.

United States

The Esaus arrived in Reedley, California, on November 16, 1922. John Esau selected Reedley because it was a Mennonite community. He planned to purchase a farm so that Katherine could apply her agricultural training, but she persuaded

him that it would be wiser for her to first find a job in a seed company and to become acquainted with the way things are done in America. In the interim, she answered a newspaper add and was hired to do housework and cooking in Fresno. She was employed by a Mr. Bursak to assist his wife and three children. Katherine had learned how to cook from her mother, and the Bursak family was especially fond of the borscht she prepared for them.

While working in Fresno, Ms Esau met Mr. Julius Siemens, a land salesman, who found employment for her in Oxnard, California, with a Mr. Sloan from Idaho. Sloan was starting a seed production ranch, with sugar beet seeds of prime interest. Ms Esau began this job in 1923 and found it to be quite difficult. Her duties included hiring a farmer with a team of horses and equipment to prepare the soil for planting, learning Spanish to communicate with the Mexican laborers, and planting the selected seed by hand. She also was responsible for testing seeds in the laboratory and sewing seed sacks closed for storage. Her least favorite job was poisoning ground squirrels, which were eating the steckling beets. After only a year, Mr. Sloan declared bankruptcy. The resident manager for Sloan's ranch, Mr. GE Bense, found a job with the Spreckles Sugar Company in Salinas and suggested that Ms Esau apply for a job there.

When Spreckles discovered that I knew what I was doing, they provided me with independent transportation. First, I had a model-T Ford, later a much used Studebaker. As was to be expected, there were some hilarious incidents of getting stuck in the mud along an irrigated field, or having one's tire take a notion to roll ahead of the car. I always had a book with me for the eventuality that I would have to wait for help along the highway.

Spreckles

Ms Esau joined Spreckles Sugar Company in 1924. Her main task was to develop a sugar beet resistant to the curly-top disease. The name curly-top refers to the curling of the leaves on diseased plants, which also were severely stunted. The disease was known to be caused by a virus transmitted by the beet leafhopper, first called *Eutettix tenella*, but later renamed *Circulifer tenellus*.

Ms Esau drove 50 miles each day to the beet fields that were owned or rented by Spreckles. She walked the rows of beets and placed stakes next to the plants that seemed to survive the curly-top infection. At harvest time, a laborer and she walked behind the plow that was lifting the beets and collected those that were marked with the stakes. These "mother beets" provided the starts for raising seed for the next year. The work progressed nicely and in 1930, when she was a graduate student at Berkeley, Ms Esau published her first paper. This paper dealt with the history of the sugar beet and the results of her research on the breeding of a curly-top-resistant strain of beets (4).

While working for Spreckles, Ms Esau began to consider going back to school. Unexpectedly, Dr. WW Robbins, Chairman of the Botany Division at



Figure 3 Katherine Esau near her home, Davis 1937. (Photo by F.P. Mc Whorter.)

what was then the University Farm of the University of California, Berkeley, and Dr. HA Jones, Chairman of the Truck Crops Division at Davis, visited Spreckles to see what was being done about the curly-top problem. Ms Esau took them in her old Studebaker to her plots in the Salinas Valley and showed them the beet fields and results of her work. At that time she inquired about the possibility of doing graduate work at Davis. Dr. Robbins immediately accepted her and appointed her as an assistant in his division. Ms. Esau left Spreckles in 1927, in her Studebaker, with a truckload of beets and beet seed.

I arrived in Davis in the fall of 1927 and found much activity on the campus in preparation for a football game—an unfamiliar event for me. For living quarters, I was given a room in a dormitory. Since the campus had only a few female students, rooms were made available to single female employees.

Graduate Work—University of California, Berkeley and Davis

In spring 1928, Katherine Esau registered as a graduate student at UC Berkeley since Davis did not have a graduate school at the time. TH Goodspeed, the *Nicotiana* cytologist in the Department of Botany at Berkeley, served as her advisor. Ms Esau took many courses at Davis, but also spent one semester at Berkeley where she took Goodspeed's course in plant cytology, NL Gardner's course in cryptogamic botany, and AR Davis' course in advanced plant physiology.

Ms Esau's original research plan was to develop a curly-top-resistant sugar beet. This plan had to be abandoned, however, because Davis proved to be a poor area for the propagation of the leafhopper vectors of curly-top. In addition, the Truck Crops Division at Davis was beginning a project for standardizing varieties of table beets and they did not want infected leafhoppers near the plots. Ms Esau discussed these problems with Dr. Robbins, who proposed that she study the effects of the curly-top virus on the plant. This marked the beginning of Katherine Esau's exceptional and productive 64-year career in plant anatomy.

Ms. Esau took her qualifying exam in September, 1930, before six examiners: WW Robbins, JT Barrett, JP Bennett, RE Clausen, AR Davis, and HA Jones. She passed the exam and was advanced to Candidacy. One year later, she completed her thesis and took a final examination from her research committee: WW Robbins, TH Goodspeed, and TE Rawlins. The PhD was awarded on December 19, 1931, and formal granting of the PhD occurred at the Berkeley Commencement of 1932. Dr. Esau was also elected to Phi Beta Kappa in 1932.

The question about employment was before me now. Dr. Robbins was willing to appoint me at the lowest academic rank as Instructor in Botany, but after consultation with Dr. Borthwick, the position of Junior Botanist in the Agricultural Experiment Station of the College of Agriculture was added. This meant an 11 month appointment instead of 9 months for a faculty position. I was, of course, pleased at having the research responsibility added.

University of California, Davis

Dr. Esau was assigned to teach plant anatomy, systematic botany, morphology of crop plants, and microtechnique. She was reluctant to teach at first, but proved to be an outstanding teacher. She taught with enthusiasm, and her students enjoyed her courses.

Working conditions at Davis left much to be desired. None of the teaching staff had offices. Eventually, Dr. Esau was assigned to share a teaching laboratory with Dr. Alden Crafts, the newly appointed plant physiologist. Dr. Esau enjoyed sharing space with Dr. Crafts, who was studying the phloem tissue as a possible pathway for the transport of chemicals used in weed control. Dr. Esau was becoming increasingly aware of the relationship between the phloem tissue and the spread of tissue degeneration induced by the curly-top disease.

Dr. Esau was eventually assigned to an office in a building that had been a garage. The building was partitioned into smaller rooms for offices and larger ones for classes. All available microscopes were quite rudimentary. Illumination was provided by an ordinary light bulb covered with a asparagus can. Dr. Esau decided to purchase her own microscope to use at home. She also installed a small darkroom there. The converted "botany" garage had no air conditioning, and the summer months were particularly unbearable in the "warm" Davis climate.

Dr. Esau continued her studies of noninfected and infected sugar beets during her first few years at Davis. She discovered that during development of the vascular bundles, the first functional sieve tubes and companion cells—the protophloem sieve tubes and companion cells—become obliterated. The remaining parenchymatous cells of the protophloem then develop into fibers, which previously had been erroneously considered as pericycle (5). The discovery was of great importance both for clarification of the concept of pericycle and for an understanding of the relationship of the curly-top virus to the tissues of the plant (6). This discovery provided the first evidence that the degenerative effects of the virus were initially localized in the phloem tissue.

Dr. Esau's subsequent research on the tobacco plant (*Nicotiana tabacum*), another host of the curly-top virus, strengthened the concept of the dependence of this virus on the phloem tissue for initiating and spreading the infection throughout the plant (9, 11). By inoculating single leaves with the virus, she demonstrated that the early spread of the external symptoms in the plant depended on the most direct vascular bundle (specifically, leaf-trace) connections between the leaves (11).

Dr. Esau also studied developmental features of healthy plants, including celery (7, 8), tobacco (9), carrot (10), flax (12, 13), and pear (15). The tobacco article (9) was especially important because in it she addressed several general problems of developmental anatomy, including the characters used to

distinguish between procambium and cambium and between primary and secondary vascular tissues, the origin of internal phloem, leaf-trace differentiation, and the concept of pericycle. With regard to pericycle, she chose to call these fibers that develop from parenchymatous elements of the protophloem "primary phloem fibers." By definition, pericycle should not arise in the same procambium as the nearest sieve tubes.

Dr. Esau was proving to be a thorough and competent scientist and soon received several invitations to prepare comprehensive reviews. In a 1943 review (14), she focused on the initial vascular differentiation of both phloem and xylem. This review prompted intensive discussions of morphogenic problems among botanists.

During the second world war, the Davis campus was assigned to the Army Signal Corps and teaching was suspended. Dr. Esau was asked to assist Dr. Reed Rollins of Harvard University in developing more productive rubber-yielding strains of guayule. Her task was to determine why certain polyploid strains of guayule failed to yield hybrids when crossed with other strains. Instead they produced progeny of the maternal type. Dr. Esau's developmental studies demonstrated that apomixis was the cause (16).

After completion of the guayule project, Dr. Esau turned her attention to the grapevine, both normal vines and vines infected with Pierce's disease. Developmental studies of the noninfected phloem were undertaken with special attention to the seasonal changes. In this work (17, 18), Dr. Esau clarified the phenomenon of reactivation of the secondary phloem as over-wintering sieve tubes resume a functional state at the beginning of the second growing season. The Pierce's disease agent was thought to be a virus, but later ultrastructural studies by other researchers revealed that the agent was a rickettsia-like organism.

Dr. Esau also studied other virus-related plant diseases, including barley yellow dwarf in Poaceae (20), yellow leaf roll of peach in celery (21), and beet yellows in beet and *Tetragonia* (23). She demonstrated that in each disease the effects of the virus are first detectable in the phloem as soon as the first sieve element matures.

In the 1950s, Dr. Esau began a collaboration with Dr. Vernon I. Cheadle on the comparative structure of phloem in the dicotyledons. They used two approaches to their studies. In one, the phloem of members of a small family (Calycanthaceae; 34) and a single species of a large family (*Liriodendron tulipifera* in the Magnoliaceae; 37) were studied in detail. In the second approach, various features from large numbers of species from many families were investigated. Specific features of interest were the kinds of cell divisions occurring in differentiating phloem and their final effects on cell arrangement, size, and form of the sieve elements (33); variations in cell wall thickness in the sieve elements (35); and size of sieve area pores (36). These studies were important

in discussions of the evolutionary aspects of functional specialization of the phloem tissue.

In the late 1940s, John Wiley and Sons, invited Dr. Esau to write a plant anatomy text book. She undertook the task with the same determination and enthusiasm that she showed in her research. The comprehensive treatment and the emphasis on developmental aspects resulted in a manuscript more voluminous than the publishers expected. Two reviewers, Drs. Adriance S. Foster and Vernon I. Cheadle, recommended that the book be published in its entirety. *Plant Anatomy* was published in 1953 (19, 25). It immediately became a classic and was fondly called the bible by structural botanists. Wiley and Sons wished to publish a smaller text for less comprehensive courses and, in 1960, Dr. Esau completed *The Anatomy of Seed Plants* (22, 31).

Sometimes I wonder at my impulsiveness; I am able to make decisions in five minutes. I never thought of moving away from Davis, but when Cheadle showed interest in continuing to work with me, I thought, darn it, why not, I will move to Santa Barbara. That is the way I am. I make a decision, and I go through with it.

University of California, Santa Barbara

In 1963, Dr. Esau decided to move to Santa Barbara to continue her collaboration with Vernon Cheadle, who had been appointed Chancellor at the UC campus. Dr. Esau considered her years in Santa Barbara to be her most productive and fulfilling. She had been introduced to electron microscopy just before leaving Davis and was interested in applying this new tool to her anatomical research. An electron microscope was purchased and installed in Santa Barbara soon after her arrival. Dr. Esau collaborated and published with many people during the Santa Barbara period including Vernon Cheadle, J.E. Duffus, Lynn Hoefert, Iris Charvat, James Cronshaw, R McCrum, Sally Shepardson, Andrew Magyarosy, Jennifer Thorsch, Robert Gill, Hatsume Kosakai, and Deborah Fisher.

Dr. Esau continued her studies on the structure and development of the phloem, including studies on the development of the P-protein in squash (2, 3), mimosa (29), cotton (46), and bean (32). Other aspects examined included development of sieve-plate pores (43), the nucleus and endoplasmic reticulum (45), and nuclear crystalloids, especially in the Boraginaceae (42, 44, 47). Dr. Esau also continued her studies of viruses, following their appearance and fate in plant cells. Studies on the tobacco mosaic virus contributed to the characterization of the P-protein (1). Beet yellow disease virus was the first virus studied by Dr. Esau with the electron microscope. She collaborated with James Cronshaw and Lynn Hoefert. Filamentous virus particles (virions) were found in mature sieve elements in *Tetragonia* (39, 40), where they often filled the sieve-plate pores in the place of P-protein, or combined with it. Virions were also found in the plasmodesmata connecting the sieve elements with parenchymatous elements, indicating that the virus has a special capacity to invade

cells via plasmodesmata. The presence of virus particles in the sieve elements and sieve-plate pores provided further evidence that the sieve-plate pores are open. In addition, it indicated that the beet yellows virus moves in the sieve tubes in the form of complete particles.

Perhaps the most rewarding of the virus studies were those undertaken with Dr. Lynn Hoefert on beet western yellow disease, involving the phloem-dependent virus that causes yellowing of sugar beet leaves (30, 41). Comparison of leaves of different ages from the same plant indicated a sequence in the systemic spread of the virus, beginning with virions transported in sieve tubes, followed by virions passing through plasmodesmata into parenchymatous cells capable of viral synthesis, and ending with the formation of new virus in the nucleus with some participation of the nucleolus. The results of these studies inspired Dr. Esau to write a cartoon-like story called *The Saga of Vladimer the Virus and the Tragic Fate of Norman the Nucleus*.

Dr. Esau also prepared several books for publication during her tenure at UC Santa Barbara. In 1965, *Vascular Differentiation in Plants* was published by Holt, Rinehart and Winston (26). In this book, Dr. Esau brought together her findings and thoughts about the relationship of the development of the vascular tissues to the ontogeny of the whole plant and reviewed the salient concepts of the vascular organization of the plant. The second edition of *Plant Anatomy* was published in 1965 (25). In 1969, *The Phloem* was published by Gebruder Borntraeger (28). Dr. Esau reviewed the structure and the development of the phloem beginning with the earliest records of the tissue. *The Phloem* is an excellent example of one of Dr. Esau's greatest contributions. Her mastery of languages, including French, Spanish, English, Russian, German, and Portuguese, allowed her to prepare a thorough review of the very early and important German, Russian, and French articles. Dr. Esau also wrote *Plants, Viruses, and Insects* in 1961 (24) and *Viruses in Plant Hosts: Forms, Distribution, and Pathologic Effects* in 1968 (27). In 1977, the second edition of *Anatomy of Seed Plants* was published (31).

I never worried about being a woman. It never occurred to me that that was an important thing. I always thought that women could do just as well as men. Of course, the majority of women are not trained to think that way. They are trained to be homemakers. And I was not a homemaker. My surprise at being elected to the National Academy of Sciences was not because I was a woman, but because I didn't think that I had done enough to be elected.

Honors

Katherine Esau's career has no parallel. She received much recognition and numerous awards for her outstanding research and contributions to Botany. In 1940, she was awarded a Guggenheim Fellowship for research at Harvard University with Professors RH Wetmore and IW Bailey. The Davis campus honored Dr. Esau for her research in 1946, by selecting her for the annual

Faculty Research Lecture. Accelerated advancements were rare at Davis and Dr. Esau did not wish to approach Dr. Robbins about a promotion. Even when she, as an Associate Professor, was selected to present the Faculty Research Lecture, Dr. Robbins informed her that she was not to expect any special treatment. Dr. Esau attained the rank of full professor in 1949, at the age of 51. A Certificate of Merit was awarded to Dr. Esau on the Golden Jubilee Anniversary of the Botanical Society of America in 1956, for "Outstanding contributions in the advancement of botanical science." Later, in 1957, Dr. Esau was elected to the National Academy of Sciences. In 1989, Dr. Esau was awarded the President's National Medal of Science. The citation accompanying the medal reads: "In recognition of her distinguished service to the American community of plant biologists, and for the excellence of her pioneering research, both basic and applied, on plant structure and development, which has spanned more than six decades; for her superlative performance as an educator, in the classroom and through her books; for the encouragement and inspiration she has given to a legion of young, aspiring plant biologists; and for providing a special role model for women in science."

Dr. Esau was very pleased to be selected to receive the President's National Medal of Science and said, "Receiving a medal in science... it just seems like it's a culmination—that this is as far as I can go."

Personal Remarks

Dr. Esau truly dedicated her life to science. She often remarked that she did not have particular scientific goals, but merely studied the aspects of Botany that interested her. Dr. Esau was, from her early years, a very determined woman who did not let past events or challenges deter her progress. While she early on made a decision to stay single, she had numerous suitors. She found this to be an amusing situation and often joked about the difficulties she had in discouraging several men interested in marrying her.

Dr. Esau was incredibly organized and meticulous. Her office and home desk were always neat and tidy. Her drawers were artfully arranged with pens in one compartment, pencils in another, all oriented in the same direction, and paper clips, rubber bands, and other items carefully stored in separate sections. She was equally meticulous as a person. Dr. Esau exercised every morning at 5 A.M. before beginning her day. Several days a week she also took a long afternoon walk. She did her shopping on Saturdays and, upon returning home, prepared food for the entire week. Her dietary demands were very simple; she never tired of the same menu. Before retiring, usually after midnight, she would brush her hair 100 strokes, massage her scalp, and perform a few stretching exercises. After pleasure reading for 10 to 20 minutes, she would sleep soundly until 5 A.M.

The demanding schedule that she followed suited her organized and determined personality. Aside from some evening pleasure reading, Dr. Esau's only passion was the opera. She frequently attended the opera in San Francisco with her brother Paul and even embarked on a trip to Seattle, where she and her brother enjoyed the performance of Wagner's *The Ring*. After preparing her weekly meals on Saturday, Dr. Esau would enjoy the operas broadcast on the Public Broadcasting Station.

Dr. Esau was also a very generous person with her time and resources. In 1989, she provided funds to establish The Katherine Esau Post Doctoral Fellowships in the Plant Sciences at the University of California, Davis. Upon her death in 1997, Dr. Esau donated funds to establish The Katherine Esau Endowed Chair in Structural Botany at the University of California, Santa Barbara. Her generosity in establishing positions in structural botany will provide a wonderful legacy for encouraging and promoting studies of plant structure.

Dr. Esau remained active as a researcher until 1991, when, at the age of 93, her last paper was published in the *Botanical Gazette* (38). The last years of her life were spent at her home in Santa Barbara. She died on June 4, 1997.

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