Nikolai Ivanovich Vavilov: Plant Geographer, Geneticist, Martyr of Science

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Abstract. **Nikolai Ivanovich Vavilov (1887–1943), one of the pioneers of 20th century plant breeding, is best known for seminal work in identifying centers of origins and diversity for cultivated plants. Vavilov studied genetics with William Bateson from 1913 to 1914 at the John Innis Horticultural Institute. In 1921, he was chosen by Vladimir Lenin to head the Branch of Applied Botany in Petrograd (St. Petersburg) and rose to be the Director of the All-Union Institute of Agriculture in Leningrad, where he oversaw agricultural research for the entire country. By 1934, Vavilov established more than 400 research institutes and experiment stations with a staff of 20,000. His efforts established the Soviet Union as a world leader in genetics and plant breeding in the 1920s and early 1930s. Vavilov carried out an extensive series of expeditions worldwide, including the United States, to collect germplasm; and he created the world's largest repository, over 250,000 seed accessions. However, as a result of famine in the Soviet Union in the late 1920s, partly as a result of forced collectivization of peasants, Vavilov came in conflict with an ambitious agronomist, Trofim Lysenko, who came to prominence with an agricultural technique proposed in 1928, of exposing chilled, soaked seeds of wheat (dubbed vernalization) to extend production in northern areas of Russia. Lysenko's rejection of Mendelian genetics won the support of Joseph Stalin, leading to the arrest and death sentence of Vavilov, although this was later commuted to 20 years imprisonment. Vavilov died of starvation in prison in 1943, thus entering the select group of martyrs of science along with Gordiano Bruno, Galileo Galilei, Antoine Lavoisier, and Georgii Karpechenko.**

Nikolai Ivanovich Vavilov (Fig. 1) was one of the foremost innovators of plant improvement during the first half of the twentieth century. His major achievements include the prescient Law of Homologous Variation, the concept of Centers of Origin for Cultivated Plants, the establishment of germplasm repositories (genebanks), plant breeding for disease resistance, and analyses of plant domestication. He was appointed to Director of the All-Union Institute of Agriculture in Leningrad and was instrumental in pushing the emergent Soviet Union to become a global leader in plant genetics and agricultural research in the 1920s and 1930s. His tragic downfall at the hand of Trofim Lysenko and Joseph Stalin in the late 1930s was a shameful and terrible chapter in the conflict of science and despotism. Vavilov died in prison as a martyr of science. His life and career have become an inspiration to botanists, geneticists, and agricultural scientists.

EARLY LIFE

Nikolai Vavilov was born in 1887 to a prosperous merchant family in the textile business that had come from the peasant class (Cohen, 1980), He was one of seven children, three of whom died in childhood. Two of his surviving sisters received a medical education, and his younger brother Sergey Ivanovich Vavilov (1891–1951) became a distinguished physicist known for his work in physical optics and luminescence, and as codiscoverer of the Vavilov-Cherenkov effect, for which Pavel Cherenkov was awarded a Nobel Prize in 1958. Sergey Vavilov rose to President of the USSR Academy of Science, and was the recipient of four Stalin Prizes (1943, 1946, 1951, and 1952).

As a boy Nicolai was interested in natural science and developed a personal herbarium. He had hoped for a medical career, but as he was untrained in Latin—a deficiency that he would later master—he enrolled in Moscow Agricultural Institute (Fig. 2). He studied plant physiology and bacteriology, and graduated in 1911. His BA diploma essay was on snails as pests, and later studies would earn him a gold medal of the Moscow Polytechnic Museum. Vavilov continued postgraduate work under the soil scientist Dmitrii Nicolaevich Prianishnikov, and in 1911 and 1912 he taught summer courses at the Golitsyn Women's Agricultural School, founded by Prianishnikov. From 1911 to 1917, Vavilov focused on seed selection and breeding with Dionazas Leopold'dovich Rudzinskas, investigating plant immunity to disease. In 1911–1912, Vavilov performed practical studies at the Bureau for Applied Botany and at the Bureau of Mycology and Phytopathology of the Agricultural Scientific Committee. During 1913–14, he continued his education in England in and had fateful interactions with William Bateson of the John Innis Horticultural Institution, the first person to use the term genetics (Fig. 3); Roland Biffen, a geneticist and agricultural botanist at the University of Cambridge; and Sir John Percival, a wheat scientist at the University of Reading. He visited the Vilmorin Institute in France, and Ernst Haeckel, a pioneer in evolutionary genetics, in Jena, Germany and returned home at the outbreak of World War I.

SCIENTIFIC CAREER

In 1917, Vavilov was nominated as Deputy Head of the Bureau for Applied Botany. He continued his investigations and was awarded the title of Professor of Saratov University in 1918. In 1921, he was chosen by Vladimir Lenin to head the Branch of Applied Botany in Petrograd (Leningrad in 1924 and Saint Petersburg since 1991) and became the Director of the V.I. Lenin All-Union Institute of Agriculture in Leningrad, where he administered agricultural research for the entire country. In 1924, the Department of Applied Botany was retitled the Institute of Applied Botany and New Crops (VIR since 1930) and

Fig. 1. Nikolai Ivanovich Vavilov, 1887–1943.

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became the central nationwide institution responsible for collecting world plant diversity and studying it for the purposes of plant breeding. In 1922, Vavilov headed the Institute of Experimental Agronomy which in 1930, became the V.I. Lenin All-Union Academy of Agriculture. Vavilov was the first president, serving from 1930 to 1935. From 1930 to 1940, he was director or the Institute of Genetics (Fig. 4) and organized significant national and international scientific meetings and congresses on botany, genetics, plant breeding, agricultural economy, and the history of science. By 1934, Vavilov established more than 400 research institutes and experiment stations throughout the Soviet Union, with a total staff of 20,000.

Vavilov's early scientific work involved plant immunity to disease, which culminated in a book, *Theory of Immunity of Plants to Infectious Disease* (1919) followed by a two-volume work, *The Theoretical Basis of Plant Selection.* In 1920, Vavilov presented a paper at a conference of plant breeders in Saratov entitled *The Law of Homologous Series in Hereditary Variability* (later published in the 1922 *Journal of Genetics*), one of the major contributions on which his worldwide reputation is based. He was to be lauded as the Mendeleev of Biology! Vavilov listed and arranged plants in a way that made prediction of new undiscovered forms (missing links) possible. The law held that there is parallel variability of homologous or similar characters in taxonomically near species. The basis for these changes has recently been explained by gene synteny, and this will be discussed in a paper by Keith Folta in the present workshop.

Fig. 2. Young Vavilov wearing student uniform of the Petrovaskaya Agricultural Academy, 1909.

Fig. 3. Vavilov and William Bateson, 1913.

The origin of cultivated plants drew his attention, and an early work entitled *On the Origin of Cultivated Rye* was published in 1917, incorporating linguistic analysis. This work presaged Vavilov's main contribution expounded in 1926, and published as *The Centers of Origin of Cultivated Plants*. It was appropriately dedicated to Alphonse De Candolle, Swiss botanist and early plant geographer and author of the pre-genetic and pre-cytological classic, *The Origin of Cultivated Plants* (1880), which predicted that cultivated plants originated in areas inhabited by their wild relatives. Vavilov later expanded his concept in a book entitled *Theoretical Basis of Plant Breeding* (1935). He noted that the success of breeders such as Ivan V. Michurin, Luther Burbank, and Niels Hansen were based on their use of exotic germplasm from distant regions. Eight Centers of Diversity were enumerated: I. China, II. India and Indo-Malaya, III. Central Asia, IV, Near East, V. Mediterranean, VI. Abyssinia, VII. South Mexico and Central America, and VIII, South America (Peru, Ecuador, Bolivia). His centers were refined and regrouped as new findings were made. Vavilov was honored for this work with the Lenin prize, and named as a foreign member of the Royal Society of London.

Vavilov and the Centers of Origin will be treated by Kim Hummer and James Hancock in this workshop. In a further work, *The Geographic Principles of the Distribution of Genes in Cultivated Plants*, Vavilov asserted that the centers of origin would be the principal course of dominant traits and that the economically important recessive traits would be found concentrated beyond the boundaries of these centers. Vavilov's work was expanded by Jack R. Harlan of the University of Illinois, who critically redefined these Centers into Centers and Non-Centers (Harlan, 1971, 1992). The revision is ongoing.

Fig. 4. Vavilov in Leningrad with map of his Centers of Origin of cultivated plants, inspiration for his global seed bank.

Vavilov is considered one of the foremost plant geographers who had the vision to establish a world collection of seeds embracing all variation. He initiated the concept of the genebank, which has become an essential tool of modern plant conservation and breeding. His seed collection grew to 250,000 entries by 1940 (Leppik, 1969). Starting with

his first expedition to Persia in 1916, during the First World War, Vavilov made a total of 115 research expeditions to 64 countries in five continents to collect diversity. Vavilov's expeditions will be covered by Kim Hummer in her pape*rs* in this collection. His principal equipment was the mule. In 1932, he collected wild sunflower in the United States and as a result of this introduction to the Soviet Union, a stable hybrid of sunflower was created that was reintroduced to the United States in 1972 (Nabhan, 2009). His last expedition was made to Soviet-occupied Poland, when he was arrested by the Soviet Police as a result of the Lysenko Affair, as discussed below.

THE LYSKE NO AFFAIR

The rise and fall of Vavilov is a chronicle of fame and shame. Vavilov's assent in Russian agricultural science was meteoric. His fame was international. He was inducted into numerous foreign academies and societies and was awarded an honorary doctorate from Higher Agricultural School Brno, Czechoslovakia in 1936. In 1932, he served as vice president of the Sixth International Congress of Genetics, held in Ithaca, New York (Fig. 5). In 1939, he was elected honorary president of the Seventh International Congress of Genetics, held in Edinburgh, but travel of all Russian scientists was canceled, and he was unable to attend.

His downfall, disgrace, and death was a direct consequence of his conflict with Trofim Lysenko, which has been referred to as "The Lysenko Affair" (Crow, 1993; Pringle, 2009). The origins have multiple threads but the issue that proved most dangerous was the interplay of science and politics. The early objection to the new science of genetics (called Mendelism in Russia) was part of an international misunderstanding between genetics and evolution, a controversy that was not fully settled until the pioneering work of population genetics spearheaded by R.A. Fisher that reconciled evolution with genetics. The role of plant selection by the Russian pomologist Ivan Vladimirovich Michurin (Fig. 6), a similar persona to Luther Burbank in the United States, created a split between fundamental genetics research by scientists and applied breeding efforts by men who did not understand genetics, and furthermore had erroneous theories of inheritance. Belief in the inheritance of acquired characteristics proposed by Jean-Baptiste Lamarck was to have an important role when for political reasons the concept of changing inheritance by nurture was considered to have fit communist ideology. As a result, modern genetics (Mendelism-Morganism) was considered to be reactionary, bourgeois, and capitalistic.

At the famous All Russian Genetics Congress held in Leningrad in 1929, a paper by Trofim Lysenko (Fig. 7) entitled *Concerning the essence of the winter habit* brought Lysenko into prominence. Although what was to be dubbed vernalization had been long a subject of physiological study in the 19th century, Lysenko initiated the practical benefits of this practice by using chilled seed of winter wheat to allow spring planting in northern areas. He used this as a platform to attack genetics, making the assumption that a quicker environmental change could transform wheat, and later erroneously asserted that these changes could be inherited. The number of hectares planted to vernalized wheat increased from 43,000 in 1932 to 10 million in 1937, but by 1945, this technique was no longer in use. Lysenko, a dour, mean-spirited agronomist, advanced his unscientific theories with political acumen. Interestingly he was originally supported by the ever-tolerant Vavilov, who also brought Michurin into prominence, but it was to no avail. Lysenko was also opposed to hybrid maize, and when he became President of the Lenin Academy of Agricultural Science in 1938, research ceased.

Fig. 5. Vavilov with Thomas Hunt Morgan and Nicolay Timofeyev-Ressowsky at the Sixth International Genetics congress in Ithaca, NY.

Lysenko came into prominence and power when Josef Stalin considered inheritance of acquired characters as accepted dogma. This turned out to be the turning point to the destruction of Vavilov's career and life. In 1935, Vavilov was replaced as President of the Academy and the 25th jubilee year of celebration of Vavilov was canceled. The opposition to Vavilov was to become tyrannical, and by 1936 arrests of geneticists started to be made, including I.I. Agol and Solomon Grigor'evich Levit. When the Seventh International Congress of Genetics was transferred to Edinburgh, Scotland in 1939 with Vavilov elected as honorary Chairman, the entire Soviet delegation including Vavilov was forbidden to attend. When Lysenko was appointed President of the Lenin Academy on Feb. 18, 1938, the former presidents, G.I. Meister and A.I. Muralov, were arrested. Vavilov fought back to no avail. In

1939, at the Leningrad Institute he uttered his fateful comment: "We shall go to the pyre, we shall burn, but we shall not retreat from our convictions (Pringle, 2009, p. 231)."

The arrests eventually led to judicial murder; Gerogii Karpechenko, author of the classical paper on allopolyploidy (Ryder, 1989), was shot in 1941. Vavilov soon realized his opponent was not Lysenko but Stalin. The beginning of the end came in 1940, after a vitriolic private exchange with Lysenko. Vavilov continued working and completed his late work *World Varietal Resources of Grain Crops.* In that year, as a consequence of the Molotov-Ribbentrop Pact and the occupation of part of Poland by the Soviet Union, Vavilov headed a small expedition to study economic and wild plants in Eastern Poland (Western Ukraine). During this expedition, a car approached and Vavilov was unceremoniously taken back to back to Moscow under custody. A letter from the NKVD chief Lavrentiy Beria, head of the infamous NKVD, to Molotov was later found, requesting permission for the arrest. Vavilov was charged with belonging to a rightist conspiracy and spying for England. Confessions were obtained under torture but later denied. He was convicted as charged and sentenced to death. The sentence was commuted to 20 years imprisonment, perhaps due to the intervention by Prianishnikov, his aging professor, who had a student who was the wife of Beria.

Vavilov was evacuated to Saratov in 1941 (Fig. 8). His life was to cease in the city where his star had once risen. He died in prison on 26 Jan. 1943, of cardiovascular failure and dystrophy at the age of 55—undernourished and sick as a result of solitary confinement (Fig. 9). He was to become a nonperson, and his name was never mentioned until his subsequent rehabilitation in the 1960s. In 1948, Lysenko in the infamous August session of the Lenin Academy of Agricultural Sciences gave his hand away when he proclaimed that the Central Committee of the Communist Party had approved his speech *The Situation in Biological Science*. "Michurinist biology" was proclaimed the correct path and "reactionary Mendelism-Morganism" was considered heresy and error. The role of Stalin in determining biologic orthodoxy became a frightening aspect of despotism, equivalent to the worst example of the Inquisition in which the heliocentric model of Galileo was proclaimed apostasy, and those

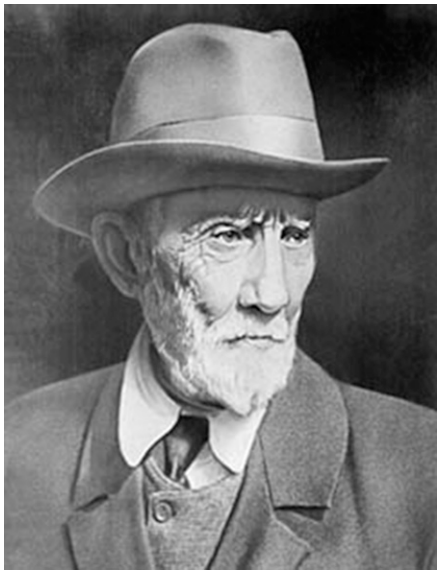

Fig. 6. Ivan Vladimirovich Michurin, 1855–1948.

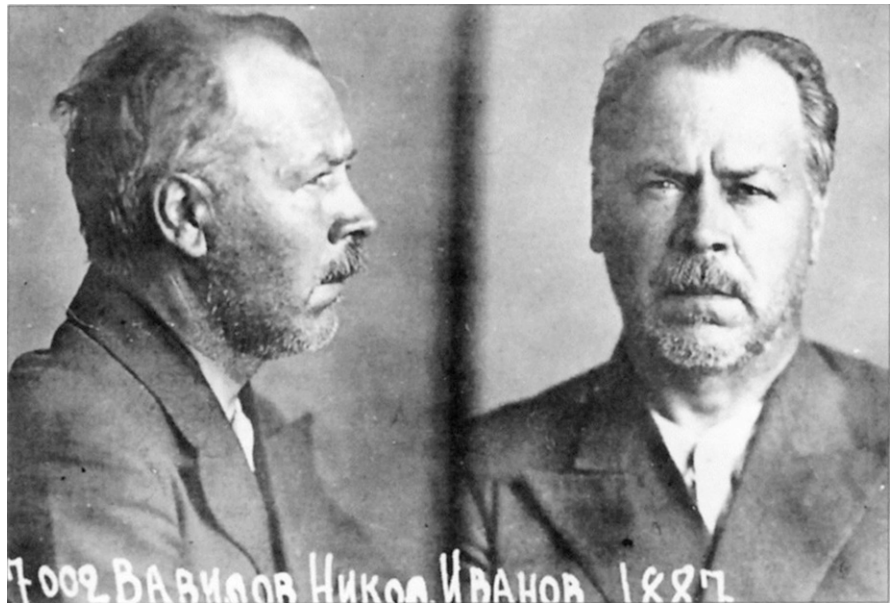

Fig. 8. Mug shot of Vavilov after arrest in 1940.

Fig. 7. Trophim Lysenko, 1898–1976.

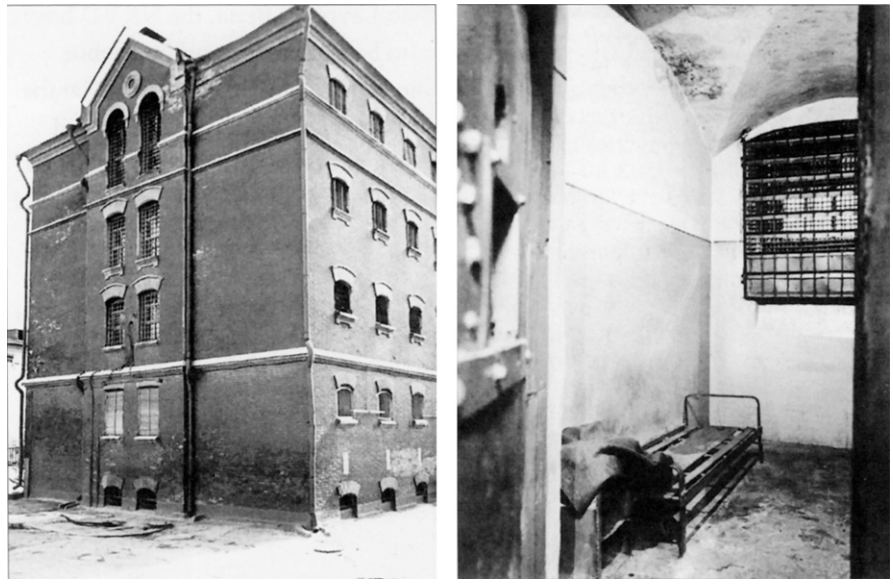

Fig. 9. Saratov prison and cell of Vavilov where he died in 1943 of cardio vascular failure and dystrophy at the age of 55, undernourished and sick as a result of solitary confinement.

Fig. 10. Vavilov honored in Russian postage stamps after his posthumous official rehabilitation in the Soviet Union.

who adhered to it were to be burned unless they retracted.

EPILOGUE

Nicolai Vavilov was an extremely attractive man, well read, likeable, and tolerant, with an engaging personality. Exuberantly energetic, a tireless worker with a photographic memory, multilingual, and brilliant, he learned local languages and embraced farmers. He was internationally known and respected by geneticists and plant breeders. His scientific work was extraordinarily productive. He published widely and as a man of action was able to carry out a tremendously productive program of experimental stations, collections, and research stations. However, Vavilov had the misfortune of coming into the crosshairs of despotism and was ruthlessly destroyed. His work turned out to be his heritage, and his stature has increased over time, while his opponents, as Torquemada, will be only remembered in infamy.

The memory of Vavilov had been preserved by his followers, who gathered up and preserved manuscripts, documents, and pictures. After Vavilov's official rehabilitation (Fig. 10) after the death of Stalin, hundreds of books and articles devoted to his life and scientific accomplishments were published. Memorial displays have been opened in Moscow, Saint Petersburg, Saratov, and Poltava. The name of Vavilov is now carried by the Russian Society of Geneticists and Breeders, the Institute of General Genetics of the Academy of Sciences, the Institute of Plant Industry, and the Saratov Agricultural Institute. The enduring legacy of Vavilov continues to exist and inspire humanity through the global gene banks now established through the United Nations and within sovereign countries.

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