

USSR Prominent Allelopathy Scientists- Part I (1880-1984)

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ABSTRACT

This article describes the outstanding results of allelopathy from 1880-1984 by USSR scientists. This biography includes the salient achievements of outstanding allelopathy Soviet scientists: Vladimir Nikolaevich Sukachev, Mykola Hryhorovych Kholodny, Sergei Ivanovich Chernobrivenko, Boris Petrovich Tokin. Mykola Kholodny founded and developed the theory of phytohormones, phytogenic and other organic components in atmosphere (plant volatile secretions) and methods of their biotesting, studied rhizospheric aspects of allelopathic plant interactions in soil microbiology. V.N. Sukachov formed the Principles of phytocoenological interactions of plants and chemical interactions in communities, formation of plant life strategies and laid the foundations of phytogenic fields. S.I. Chernobrivenko developed the structure of allelopathic regime in cenosis to study life strategies of plants and grouped interactions in different species in cenotic communities. V.R. Tokin, gave doctrine of 'Plant Phytoncides', which provided the basis for phytohormonal and phytoexudative interactions of plant species through secretions from roots and aboveground parts and their allelopathic actions.

Key words: Allelopathy, Allelopathy Scientists, Biography, Chernobrivenko, Kholodny, Sukachev, Tokin.

1. INTRODUCTION

The scientific biological laws are changing as the details of processes of existence of living organisms and their complex interactions are available. The mutual influences of plant spp in the biogeocenosis is basic methodological approach. Allelopathic research is becoming increasingly important, more complicated and has new outlook. Allelopathic research is mandatory to establish the biological and economic efficiency of various agrophytocoenoses, biological control of agricultural pests (Weeds, Insects, Nematode,

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Fungi) without use of agrochemicals, development of ecologically balanced biogeocenoses in different ecosystems and to prevent allergic reactions etc (284).

Allelopathic science has undergone great changes from the first research and theories in 19th century to the modern cell level-genetic studies in biological species in many countries. The success of Allelopathy science would not be possible without the contributions of 'Pioneer Allelopathy Scientists' who defended and developed the ideas of allelopathy. The first attempts to clarify the relationships between plant species, their phytotoxicity date back to ancient Greece and Rome (265). Although the term 'Allelopathy' was formulated by the eminent Austrian plant physiologist Hans Molisch (1937) published in his book '*Der Einfluss einer Pflanze auf die andere - Allelopathie*'. Despite this, parallel allelopathic studies were conducted in many countries including the former Soviet Union in the 20th century. The first attempts to elucidate the mechanism of influence in the systems of different plant species began in Russia in the early 20th century. In the 1970's and 1980's, Soviet Researchers were the world leaders in the field of allelopathy.

During the period 1930-1990, more than 5000 scientific papers and 20 Monographs were published on various aspects of allelopathy in the former Soviet Union (198,200). Many were recognized world wide as fundamental research to study the mechanisms of allelopathy. These publications provided guide for other researchers. Thus in USSR many 'Scientific Schools of Allelopathy' were established around world-renowned scientists, who continued research in their relevant areas of allelopathic science. This article highlights the key results of scientific works of former Soviet scientists, who studied many areas of allelopathic research, which developed the modern cropping system based on allelopathic science.

1.1. RUSSIAN TERMS USED AND PLANT SPP STUDIED

1.1.1. TERMINOLOGY: Russian Researchers have used various terms to explain their Results, described in (Table 1) so that Non-Russian Readers can understand these.

Table 1. Definitions of Russian Terminology

#	Term	Definition/Meaning
1	Agrophytocenology (224)	The science that studies the laws, principles, and regularities of structure, formation, and functioning of agrophytocenoses, a branch of phytocenology.
2	Anthropotolerance Plants (223)	Plants resistant to high anthropogenic impact on urban environment
3	Biocenology (232)	A branch of ecology that studies biocenosis, their occurrence, origin and development, structure and distribution in space and time, the relationship with the environment and with each other of both biocenoses and their individual components
4	Biocenosis (28)	A community of plants, animals, and microorganisms that inhabit same area of land or water and characterized by certain interrelationships among themselves and with abiotic factors

5	Biogens (244)	Substances most actively involved in the life of aquatic organisms e.g. mineral compounds of nitrogen (NH^{4+} , NO^{2-} , NO^{3-}), phosphorus (H_2PO^{4-} , HPO_2^{4-} , PO_3^{4-}), silicon (HSiO^{3-} , SiO_2^{3-}), iron (Fe^{2+} , Fe^{3+}) and some trace elements
6	Biogeocenology (222)	The science of interconnected and interacting complexes of living and space nature - biogeocenoses and their planetary totality - the biogeosphere.
7	Biomediators (187,189)	Biological chemicals occurs in all living organisms (animals, plants, microorganisms) that serve as external and intracellular signals
8	Bird Cherry (37)	Shrub plant <i>Prunus padus</i> L.
9	Cenosis (31).Biocenosis	Plants and animals inhabiting the territory with same living conditions
10	Cenosis Stratification (288)	Distribution of cenosis individuals due to dominance and type of organism formed with corresponding placement in height
11	Cenotic Regime (96)	The nature of the distribution of life strategies of individuals forming the cenosis in terms of the availability of life factors and mechanisms of adaptations and competition to ensure the survival of a particular plant species
12	Cenopopulation (278)	A group of individuals of the same species occupying a certain territory, located within the same syntax, formed under the influence of homogeneous environmental conditions and responding to them in the same way. In other words, a cenopopulation is a cenotic population, or a population within a cenosis (local ecosystem, biogeocenosis)
13	Coexistence of Plant (116,118)	The tactics of coexistence of different plant species in a single aggregate on the same territory with an appropriate level of availability of life factors
14	Cultures-acceptors (110,122)	Plant species that are most sensitive to this type of allelopathic substances of different origin and it is under the influence of this substances
15	Dissipation (216)	In the case of plant communities, the process of diffuse dispersion of substances and energy in the process of mutual competition of species and mutual influences
16	Ecotope (93)	A certain complex of environmental factors (air, water, temperature, mineral nutrition, temperature and radiation, etc.) in a certain area of the earth's surface
17	Edificators (27)	Plant species in a plant community that determine its characteristics, create a biological environment in the ecosystem and play a crucial role in shaping its structure
18	Ergonomics (95)	A science that comprehensively studies the peculiarities of human production activity in the human-plant-technology-environment system to ensure its efficiency, safety and comfort
19	Forest Allelopathy (123)	Allelopathic interaction of tree and shrub perennial plant species
20	'Friendly' Plant Relationships (27)	Synergistic coexistence of plant species in mutual positive (complementary) influence
21	Inhibition of Mutual Growth (27)	Interactions between plants that decreases mutual growth processes
22	Isoprene Theory of Plant Secretions (209,210)	The process of release of volatile isoprene compound by the assimilative surface of plants was proved, which became the basis to study interaction of plants in cenosis by volatile emissions

23	Meandering Meadow (47)	Meadows with specific vegetation, in floodplains, often in bends of river channels
24	Miasmins (160)	Compounds of different chemical nature formed as a result of soil decomposition of plant residues
25	Mixed Phytocenoses (163)	A grouping of plants of different species complexity growing on the same territory
26	Morphogenesis (164)	The process of formation, i.e. the initiation, growth and development of structures of different levels in plants: organs (organogenesis), tissues (histogenesis) or cells (cytogenesis or cellular differentiation)
27	Perianth (70)	A modified leaves in the flowers of angiosperms that surround the stamens and pistils
28	Phytocenology (233,237)	A branch of geobotany that studies phytocoenoses, or plant communities. It studies the composition, structure, dynamics and distribution of phytocoenoses
29	Phytocenotic Systems (20)	A complex of geographically distinct plant species that is determined by the number of its elements (species) and the connections between them, and for the behavior of the system - by the variety of reactions to external influences in the form of strategies. The choice of such a strategy implies the existence of goals that the system seeks to achieve. The strategic goal of phytocoenoses can be considered, for example, survival, and the tactical goal is the most favorable distribution and placement of populations to ensure maximum possible photosynthesis per unit area, the pursuit of the most stable (climax) state, etc.
30	Phytohormones (115,116)	Chemicals produced in plants that regulate their growth and development. They are formed mainly in actively growing tissues at the tops of roots and stems. Phytohormones usually include auxins, gibberellins and cytokinins, and sometimes growth inhibitors, such as abscisic acid. Unlike animal hormones, phytohormones are less specific and often act in the same part of the plant where they are formed. Many synthetic substances have the same effect as natural phytohormones
31	Phytoncides (26,253)	Biologically active substances produced by plants that kill or inhibit the growth and development of bacteria, microscopic fungi, and other forms of microorganisms
32	Plant Idiotype (288)	A set of hereditary factors of an individual. It consists of the genome, plasmid, and in green plants, plastron (from the Greek <i>ἴδιος</i> - own, special and type)
33	Plant Vitality (246)	An indicator of the vital state of an individual that ensures the implementation of a genetically determined program of growth and development. At the plant level, vitality is determined primarily by biomass (the better developed the organism, the larger it is; large, medium and small individuals are distinguished), the production process and the degree of control of the environment by the individual (for plants, the phytogenic field)
34	Self-allelopathic Incompatibility of Plant (245,246)	A pronounced allelopathic reaction of plants to plants of the same species or similar species when growing in the same area or in a link with alternation of the same plant species

35	Signal Chemical Transformations (190-192)	The nature of the plant signaling system based on the synthesis of relevant substances with their subsequent transformation at the cellular and organismal levels
36	Soil Fatigue (87,88,152,162)	Disruption of the bioenergy regime of soils and a sharp decline in crop yields as a result of their permanent cultivation or frequent return to the previous crop rotation field, which leads to deterioration of the quality of soils, accumulation of specific pathogens and weed seeds in soils
37	Stress Reactors of Plant Cell (190-192)	Systems of chemically deterministic compounds that are synthesized at the cellular level in response to relevant stress stimuli with a graded deviation from the optimal values of the relevant factors of life regimes
38	Substantiation (271)	A system of confirmation based on the data obtained, which makes it possible to formulate appropriate conclusions
39	'Sukachov's rules' (246)	For annual weeds, increasing the density of standing leads to an acceleration of their development
40	Tartar Katrana (92)	The plant species <i>Crámbe tatárica</i> L.
41	Transbiotic Relationships (246)	Indirect influence of one organism on another through a change in the conditions of existence of a third organism
42	Transbiotic Interactions (246)	Indirect effects of some plants on others through third organisms
43	Transmitter Reactions of Plant Organisms (199,201,202)	The system of signal reactions of a plant organism to disturbances of different nature in the form of synthesis of relevant substances with their point action as a variant of coordinating action of the organism as a whole and ensuring its survival

1.1.2. TEST PLANT SPP: Russian Researchers in their Allelopathic studies have used 97 plants [(i). Crops, (ii). Weeds, (iii) Medicinal/Aromatic plants, (iv). Shrubs/Flowers and (v). Trees)] (Table 2).

Table 2. Plants used in USSR Allelopathy Research

#	Russian Name	English Name	Family	Botanical name with Author
CROPS				
1	Buckwheat	Buckwheat	Polygonaceae	<i>Fagopyrum esculentum</i> L. (152)
2	<i>Camelina sativa</i>	False flax	Brassicaceae	<i>Camelina sativa</i> (L.) Crantz (27-32)
3	Castor oil plant	Ricinus	Euphorbiaceae	<i>Ricinus communis</i> L. (27-32)
4	Chickpea	Chickpea	Fabaceae	<i>Cicer arietinum</i> L. (27-32)
5	Common cumin	Cumin	Apiaceae	<i>Carum carvi</i> L. (78,79)
6	Common lentil	Lentil	Fabaceae	<i>Lens culinaris</i> L. (27-32)
7	Common pumpkin	Pumpkin	Cucurbitaceae	<i>Cucurbita pepo</i> L. (27-32,34)
8	Corn	Corn	Poaceae	<i>Zea mays</i> L. (27-32,65,102)
9	Cotton	Cotton	Malvaceae	<i>Gossypium hirsutum</i> L. (91)

10	<i>Cucumbersativa</i>	Cucumber	Cucurbitaceae	<i>Cucumis sativus</i> L. (46,73)
11	Drooping onion	Siberian Chives	Amaryllidaceae	<i>Allium nutans</i> L. (45,252)
12	Forage beans	Bean	Fabaceae	<i>Vicia faba</i> L. var. <i>major</i> Harz. (27-32,65)
13	Garlic	Garlic	Amaryllidaceae	<i>Allium sativum</i> L. (252)
14	Gray mustard	Indian mustard	Brassicaceae	<i>Brassica juncea</i> (L.) Czern (27-32,91, 285)
15	Hemp	Cánnabis	Cannabaceae	<i>Cánnabis satíva</i> L. (27-32)
16	<i>Heracleum sosnowskyi</i>	Heracleum	Apiaceae	Heracleum sosnowskyi L. (79)
17	Kenaf	Kenaf	Malvaceae	<i>Hibiscus cannabinus</i> L. (27-32)
18	Lettuce	Lettuce	Asteraceae	<i>Lactuca sativa</i> L. (21,27-32,52,77,91,93,110,229,277-282,285)
19	Long-staple flax	Flax	Linaceae	<i>Linum usitatissimum</i> L. f. <i>elongate</i> (152)
20	Lucerne	Alfalfa	Fabaceae	<i>Medicago sativa</i> L. (27,65,90,91,140,164)
21	Narrowleaf lupine	Blue Lupin	Fabaceae	<i>Lupinus angustifolius</i> L. (160,161,229, 266, 267)
22	Onion	Onion	Amaryllidaceae	<i>Allium cepa</i> L. (27-32,252,285)
23	Pea	Pea	Fabaceae	<i>Pisum sativum</i> L. (27-32)
24	Pink clover	Pink clover	Fabaceae	<i>Triphylloides rubens</i> (L.) Moench (131,164,165)
25	Potato	Potato	Solanaceae	<i>Solanum tuberosum</i> L. (27-32,110)
26	Radish	Radish	Brassicaceae	<i>Raphanus sativus</i> L. (31,52,59,77,86,89-91, 93,110, 229, 273,277-282,285)
27	Rocket-ress (Winter)	Rocket-ress (Winter)	Brassicaceae	<i>Brassica campestris</i> var. <i>oleifera</i> f. <i>bienis</i> (91,273,276)
28	Rocket-ress (Spring)	Rocket-ress (Spring)	Brassicaceae	<i>Brassica campestris</i> var. <i>oleifera</i> f. <i>annua</i> (91, 273,276)
29	Rye	Rye	Poaceae	<i>Secale cereale</i> L. (27-32,152)
30	Sowing oat	Oat	Poaceae	<i>Avena sativa</i> L. (171)
31	Soybean	Soybean	Fabaceae	<i>Glycine max</i> Moench (27-32)
32	Spring barley	Spring barley	Poaceae	<i>Hordéum vulgáre</i> L. (27-32)
33	Spring rape	Rape Seed (Spring)	Brassicaceae	<i>Brassica napus</i> L. ssp. <i>oleifera</i> Metzg. (86,89, 91, 273, 276)
34	Spring wheat	Durum wheat	Poaceae	<i>Triticum aestivum</i> L. (27-32.152,162)
35	Sugar beets	Sugar beets	Amaranthaceae	<i>Beta vulgaris saccharifera</i> L. (27-32)
36	Sunflower	Sunflower	Asteraceae	<i>Heliánthus ánnuus</i> L. (27-32,79,91,110,163)
37	Tomato	Tomato	Solanaceae	<i>Solanum lycopersicum</i> L. (27-32,46,73)
38	Turnip	Turnip	Brassicaceae	<i>Brassica campestris</i> L. (27-32,65, 86, 91)
39	White clover	White clover	Fabaceae	<i>Trifolium repens</i> L. (131,145,164,165)
40	White lupine	White Lupin	Fabaceae	<i>Lupinus albus</i> L. (91,110,160,161 229, 266)
41	White mustard	White Mustard	Brassicaceae	<i>Sinapis alba</i> L. (21,27-32,39,86,89-91,110, 273, 276,285)
42	Winter rape	Rape Seed (Winter)	Brassicaceae	<i>Brassica napus</i> L. <i>oleifera</i> (27-32,45,77,86, 89-91, 273, 276)
43	Winter rye	Rye (Winter)	Poaceae	<i>Secale cereale</i> L. (152)
44	Winter wheat	Winter wheat	Poaceae	<i>Triticum aestivum</i> L.(11-13,27-32,40,41,72)
45	Yellow lupine	Yellow lupine	Fabaceae	<i>Lupinus luteus</i> L. (160,161,229,266,267)

WEEDS				
46	Ambrosia wormwood	Ragweed	Asteraceae	<i>Ambrosia artemisiifolia</i> L. (134,145,286)
47	Blackweed	Goosefoots	Amaranthaceae	<i>Chenopodium album</i> L. (77,83,90,91,97,286)
48	Bristle grasses	Foxtail	Poaceae	<i>Setaria glauca</i> L. (42,43,286)
49	Bulb-bearing water-hemlock	Bulb-bearing water-hemlock	Apiaceae	<i>Cicuta bulbifera</i> L. (187,188)
50	Common amaranth	Common amaranth	Amaranthaceae	<i>Amaranthus retroflexus</i> L. (77,83,90,91,286)
51	Common sowthistle	Soft thistle	Asteraceae	<i>Sonchus oleraceus</i> L. (97,232,286)
52	Creeping wheatgrass	Quick grass	Poaceae	<i>Elytrigia repens</i> (L.) Nevski (42-44,77,97,145,232,286)
53	Galinsoga	Potato weed	Asteraceae	<i>Galinsoga parviflora</i> Cav. (42,43)
54	Poison chicory	Poisonous chickweed	Apiaceae	<i>Cicuta virosa</i> L. (187,188)
55	Sedum field	Thistle	Asteraceae	<i>Cirsium arvense</i> (L.) Scop. (97,232,286)
56	Spotted water hemlock	Spotted water hemlock	Apiaceae	<i>Cicuta maculata</i> L. (187,188)
57	Tartar katrana	<i>Crambe tataria</i>	Brassicaceae	<i>Crámbe tatárica</i> L. (77,78,92)
58	Western water hemlock	Western water hemlock	Apiaceae	<i>Cicuta douglasii</i> (DC.) Coult. & Rose (187,188)
59	Heart-shaped katran	Greater sea-kale	Brassicaceae	<i>Crambe cordifolia</i> Steven (133)
MEDICINAL/ AROMATIC PLANTS				
60	Caléndula	Caléndula	Asteraceae	<i>Calendula officinalis</i> L. (2,7,6,268)
61	<i>Echinacea purpurea</i>	<i>Echinacea purpurea</i>	Asteraceae	<i>Echinacea purpurea</i> (L.) Moench (2,268)
62	Fennel	Fennel	Apiaceae	<i>Anethum graveolens</i> L. (78,79)
63	<i>Hyssop officinalis</i>	Hyssop	Lamiaceae	<i>Hyssopus officinalis</i> L. (268)
64	Horsemint	Horsemint	Lamiaceae	<i>Monarda didyma</i> L. (268,270)
65	Koriandr	Kinza	Apiaceae	<i>Coriandrum sativum</i> L. (78,79)
66	Lavandula	Lavandula	Lamiaceae	<i>Lavandula angustifolia</i> L. (268) <i>Lavandula latifolia</i> L. (268) <i>Lavandula vera</i> L. (268) <i>Lavandula spica</i> L. (268) <i>Lavandula stoechas</i> L. (268)
67	Serpentine snakehead	Moldovan dracocephalum	Lamiaceae	<i>Dracocephalum moldavicum</i> L. (268,270)
68	Muscat sage	Clary sage	Lamiaceae	<i>Salvia sclarea</i> L. (6,158,268,275)
69	Parsley	Parsley	Apiaceae	<i>Petroselinum crispum</i> L. (78,79)
70	Peppermint	Peppermint	Lamiaceae	<i>Mentha piperita</i> L. (268)
71	Tagetes	Tagetes	Asteraceae	<i>Tagetes erecta</i> L. (268) <i>Tagetes patula</i> L. (268) <i>Tagetes tenuifolia</i> L. (268)

SHRUBS, FLOWERS				
72	Actinidia	Actinidia	Actinidiaceae	<i>Actinidia arguta</i> (Sieb.) Planch. (83,136, 137,151, 292)
73	Common lilac	Lilac	Oleaceae	<i>Syringa vulgaris</i> L. (95,101)
74	Common privet	Ligustrum	Oleaceae	<i>Ligustrum vulgare</i> L. (95)
75	Common viburnum	Viburnum vulgaris	Adoxaceae	<i>Viburnum opulus</i> L. (95,136,137,151)
76	Dogwood	Cornelian Cherry	Cornaceae	<i>Cornus mas</i> L. (136,137,151)
77	<i>Henomeles japonica</i>	Chaenomeles	Rosaceae	<i>Chaenomeles japonica</i> Lindl (136,137,151)
78	Grape	Grape	Vitaceae	<i>Vitis vinifera</i> L. (12,13)
79	Multifloral olive	Gummy	Elaeagnaceae	<i>Elaeagnus multiflora</i> Thunb. (136,137)
80	Padus	Bird cherry	Rosaceae	<i>Prunus padus</i> L. (34,35,37)
81	Rhododendron	Yellow azalea	Ericaceae	<i>Rhododendron luteum</i> Sweet (95,101)
82	<i>Schisandra chinensis</i>	Lemongrass Chinese	Schisandraceae	<i>Schisandra chinensis</i> (Turcz.) Baill. (136,137,151)
83	Wrinkled rose	Rósa	Rosaceae	<i>Rósa rugósa</i> L. (95)
TREES				
84	Birch	Birch	Betulaceae	<i>Betula pendula</i> Roth (47,48,183,243)
85	Common abricot	Abricot	Rosaceae	<i>Armeniaca vulgaris</i> Lam. L. (139,148–150,271)
86	Common ash	European ash	Oleaceae	<i>Fraxinus excelsior</i> L. (121,168,169)
87	Common beech	European beech	Fagaceae	<i>Fagus sylvatica</i> L. (121,168,169)
88	Common linden	Linden	Tiliaceae	<i>Tilia cordata</i> Mill. (4.48,49,88,89,91, 95,101,119-125, 166-170, 172,173)
89	Common maple	Maple	Sapindaceae	<i>Acer platanoides</i> L. (4.48,49,88,89,91, 95,101,119-125, 166-170, 172,173)
90	Common oak	Oak	Fagaceae	<i>Quercus robur</i> L. (4,48,49,88,89,91,95,101,119-125, 135–138, 139,166-170,172,173)
91	Domestic apple	Apple	Rosaceae	<i>Malus domestica</i> (L.) Borkh. (24,25,62,139,148–150, 183, 188,271)
92	European Hornbeam	Hornbeam	Betulaceae	<i>Carpinus orientalis</i> L. (4,119-125,166-170,172, 173)
93	European spruce	Spruce	Pinaceae	<i>Picea abies</i> L. (4,47,48, 111-118,119-125, 135–138,154-157, 166-170,172,173, 248, 252-260)
94	Horse chestnut	Chestnut	Sapindaceae	<i>Aesculus hippocastanum</i> L. (4,119-125, 139,166-170,172, 173)
95	Peach	Peach	Rosaceae	<i>Prunus persica</i> (L.) Batsch (139,148–150))
96	Pyramidal poplar	Lombardy poplar	Salicaceae	<i>Populus pyramidalis</i> Moench (203-220, 234)
97	White Acacia	Acacia	Fabaceae	<i>Robinia pseudoacacia</i> L. (114-118,119-125,135–138,166-170, 172,173,203-220,234,292)

1.2. SCIENTIFIC SCHOOLS OF ALLELOPATHY RESEARCH

Soviet schools for the study of allelopathy can be divided into many basic areas. These schools were based on the development of scientific approaches to study Plant physiology, Soil microbiology, Phytocenology and development of instrumental and laboratory research. These schools were led by prominent Allelopathy scientists.

1.2.1. M.G. KHOLODNY SCHOOL (1906-1970)

It studied general aspects of plant relationships in phytocenology, competition between species for existence and nutrition, started the study of secretory functions of plants. It continued with works of V.N. Sukachova (237-246) and T.A. Rabotnova (164,165). Later, (1970-1990) phytocenological approaches to study plant cenoses, life tactics of plants, nature of their interspecific relationships were studied by V.M. Mirkin (140-145) and Yu.A. Zlobin (286-291). Researchers developed many world-famous methodologies of botanical and physiological description of plants, (i). criteria for phytocenological relationships between plant species within cenoses, (ii). basic postulates of competition and life strategies of plants, (iii). defined the cenosis stratification, plant idiosyncrasy, phenological periodicity of plant growth and development. Based on these results, the fundamentals of modern phytocenology were formed, used by Botanists and Physiologists to study competition in plant species: Morphogenesis, Suppression, Dominance, Neutrality, etc. Other scientists elucidated the competition between species based on the chemical aspects of plants in the soil-plant-air system and mutual existence of plant species in natural and artificially created agrophytocenoses. M.G. Kholodny scientific ideas were divided into two groups (36). (i). Study of peculiarities of vegetation formation in view of the edaphic features of territory and microbiological connections in the rhizosphere. (ii). Study and identify volatile plant secretions. Based on these research areas, M.G. Kholodny developed the idea of 'Chemical interaction of plants and their coexistence' his ideas of volatile plant secretions were developed and refined by G.A. Sanadze (203-220,234) and developed isoprene theory of plant secretions.

1.2.2. B.P. TOKIN SCHOOL (1925-1950)

Tokin developed and generalized model of volatile plant secretions (2,36) based on concepts of M.G. Kholodny. He did detailed studies on physiological, anatomical and chemical aspects, to clarify the role of such secretions and their identification, which he called volatiles (252-260). He studied their chemistry, effects on other plant species, circulation and assimilation. He classified the phytoncides and their uses in various fields, including medicine to treat infectious wounds and ulcers, to prevent infectious diseases (284). Due to the research in medicine, homeopathic use of plants to treat infections, general health was developed. The foundations were laid to improve soil chemistry by cultivating certain plant species in certain areas (288). He studied the excretory functions of wood species and isolation of their volatile compounds (256). B.P. Tokin school had many followers [M.X. Chaylakhyan (7-13), A.A. Chasovennaya (14-25), B.S. Drabkin (37,38), V.P. Dadykin (33,34), T.I. Golomedova (47,48), I.M. Golubinsky (67-72), N.I. Mokhova (147) and V.I. Shanda (223-233)].

A.A Chasovennaya (14-25) did fundamental research on phytoncide substances cycle in nature and their role in growth of different plant species with their mutual influence in the phytocenosis. M. X. Chailakhyan (7-13) introduced the phytoncide scheme, for inhibition and control of undesirable biological organisms and also stimulatory effects of some secretions for adaptation to stress and strengthen the immune response.

Excretory function of plants: The scientific schools M.G. Kholodny and B.P. Tokina in the 60's developed another area of allelopathic research 'Excretory function of plants'. It was based on the chemical identification of plant secretions to establish clear mechanisms of mutual influence on plants in the cenosis at different levels of physiological activity (rhizosphere, aboveground parts of plants, plant residues, etc.). These studies elucidated the role of such secretions in biogeocenosis, their impact on sustainability of the plant-environment system and search for regulatory means of influencing plant growth processes. Initial studies were done on root secretions of plants, transpiration aspects of chemical secretions in works of A.A. Chasovennaya (16,17), B.S. Drabkin (38), G.A. Sanadze (205,208,209), M.V. Kolesnichenko (119-124) and V.D. Roshchina (180-186). Later detailed studies were done by V.D. Roshchina (186,187), V.V. Roshchina (186-201) and P.V. Yurin (277-282) on the formation of system of biologically active chemical compounds of allelopathic nature at the cellular level, the formation of biomediators, signal chemical transformations, stress reactors, including interactions of plant species in complex coenotic groups. This direction was further developed to study the behavioral mechanisms of plants by assessing the main reactions of cells to chemicals, the synthesis of relevant substances and their role in plant life strategy and adaptive tactics of their relationship with other species in cenoses of different levels. In this regard, special attention deserved the findings of V.D. Roshchina, Professor (Forestry) and Head, Department of Botany, Pedagogical Institute of Voronezh and her daughter V.V. Roshchina who conducted researches on allelopathy since her college days. These scientists deepened the allelopathic research at the cellular level, analyzed and generalized the excretory function of plants, signal and transmitter reactions of plant organisms, developed a number of original methods to determine the chemistry of physiological function of plants (183,201).

1.2.3. A.M. GRODZINSKY SCHOOL (1926-1988)

From the very beginning, in-depth allelopathy studies were done by foreign and Russian scientists to develop Allelopathy as a separate science, with the formulation of its fundamental laws, development of appropriate methodological and experimental framework and a complex combination of all possible theories in allelopathy (1,61,66,282). A.M. Grodzinsky aimed not only to theoretically study the allelopathy, but also its practical application to ensure the ecological stability of the territory, environmental protection, development of new crop production technology, to develop long-term vegetation associations (3,26,131,133,202). His allelopathy research began with detailed studies of the work of former Russian (pre-Soviet) researchers from 1908-1913 [D.N. Pryanishnikova (162), F.T. Pereturin (152) and others (74,84,263)], who had studied soil fatigue, depending on the crop and the influence of predecessors on the growth and development of subsequent crops. He also took into research of S.I. Chornobrivenko (27-32), on the plant interactions, impact of some plant species on others in crop rotation and monoculture in field of agronomic allelopathy. Grodzinsky also analyzed the works of Kholodny (111-118,180), Tokin (252-260) and other researchers (100). He published thematic collections on phytoncides and their circulation in the biocenosis (154-156).

In early 1960's, A.M. Grodzinsky defined the allelopathic research as fundamental for agrarian science. He formulated his scheme of plant interactions, natural forest biocenoses, artificial forest plantations, competition between different species of trees (77). Till the 1990's, his school has scientists from Belarus, Moldova, Ukraine and Russia. The developments of his school (75,76) are following:

- (i). Basic aspects of chemical interactions of plants (77-79,81,85,92),
- (ii). Phytoncide aspects of allelopathic interaction (82,86,90,91,95),
- (iii). Soil fatigue (87-89),
- (iv). Rhizosphere factors of allelopathy (79,93,94),
- (v). Microbiological aspects,
- (vi). Chemistry. methodology and identification of chemically active allelopathic compounds (79,93),
- (vii). Bioassays,
- (viii). Allelopathic potential of a number of cultivated and introduced plant species (83, 99),
- (ix). Tree and shrub species (88),
- (x). Fruit and berry crops (83),
- (xi). Dominant weed species (84,97,98),
- (xii). Allelopathic principles of plant interaction in compatible cenoses of different origin (77,82,96,221,234).

Grodzinsky's school also studied the practical aspects of allelopathic principles of phytodesign (82,101), construction of artificial cenoses (77,96), bioindications of natural coenotic systems and ecotopes (93), space biology (90). He studied the application of volatiles in co-cultivation of crops (77). He also studied the relationships between species of cultivated plants and developed the concept of beneficial and harmful predecessors in crop rotations (86,87). In the phytodesign aspects of allelopathy, the formation of landscape associations of plants, the study of forest-steppe and steppe cenoses, he developed the phytocenological aspects of allelopathic research (99).

His school published more than 1700 Articles, 20 Monographs, 30 Dissertations on allelopathic aspects (26,126-129). Under his Guidance, following scientists completed:

(A). Candidates Of Biological Sciences: T.M. Filipovich (45), N.I. Prutenska (160,161), V.M. Gaidamak (46), V.M. Olekiewicz, L.S. Seredyuk (222), T.P. Bukolova, B.B. Mitin, G.P. Bogdan, O.Yu. Kostroma, V.A. Derevyanko, S.O. Gorobets (73), T.S. Shrol, G.A. Pobirchenko (158), G.P. Kushnir.

(B). Candidates of Agricultural Sciences: N.N. Dzyubenko (40-44), N.I. Petrenko; doctors of biological sciences – G.G. Baranetsky (7), П.А. Moroz (148-150), E.A. Golovko (49-66).

(C). Doctor Of Agricultural Sciences: L.D. Yurchak (265-276), V.Ya. Maryushkina (134) etc.

Grodzinsky Scientific School developed following Allelopathy Research Areas:

- (i). **Soil sickness and substratum** (T.M. Filipovich, L.D. Yurchak, P.A. Moroz, S.G. Leshenko, L.I. Krupa, T.P. Bukolova, S.A. Gorobets, T.M. Bilyanovskaya, E.A. Golovko, V.M. Haydamak, T.S. Shroll etc).
- (ii). **Effects of phytoncides on other plants and humans** (N.I. Prutenskaya, Yu. G. Kovalchuk, V.V. Snizhko);
- (iii). **Allelopathic features of certain species of plants** (L.P. Stepanova, I.I. Popivsky, P.A. Moroz, N.I. Prutenskaya, T.M. Cherevchenko, V.Ya. Maryushkina, G.G. Baranetsky (4), A.D. Bobrova, N.N. Dzyubenko, M.O. Panchuk, N.I. Petrenko, G.P. Bogdan (6), S.V. Petrenko, V.A. Derevyanko etc);
- (iv). **Physiological and biochemical bases of interactions** of different types of plants among themselves and with microorganisms (E.A. Golovko, N.N. Dzyubenko);
- (v). **Physiological and phytocenological role of volatile secretions** of putrefactive plant mass (miasmins) (N.I. Prutenskaya);
- (vi). **Structural and physiological action of active substances of crop and weeds residues** (T.P. Bukolova);
- (vii). **Physiological and biochemical bases of interaction of higher plants and microorganisms** in natural and artificial ecosystems, species composition of soil microbial complexes at different saturation with individual plant species (E.A. Golovko, L.V. Podoba, L.S. Serdyuk);
- (viii). **Stress factors for the synthesis of allelopathically active substances** (O.V. Maidebura, V.K. Puzik);
- (ix). **Allelopathic processes in natural phytocenoses studied the influence of root secretions** on the supply of nutrients to plants, the problem of allelopathic active substances of *Heracleum sosnowskyi* Manden, steroidal saponins of sunflower, one type of onion (*Allium nutans* L.) and its biological activity in the Ukrainian steppe nature reserve) (T.M. Filipovich, G.E. Zhamba, L.S. Akhov, N.E. Ellanska);
- (x). **Allelopathic potential of weeds** (study of mechanisms of allelopathic autoregulation of population density of perennial weeds; issues of phytocenotic and allelopathic relationships of *E. repens* and their allelopathic regulation; allelopathic aspects of quarantine weeds; development of biological and phytocenotic features based on the results of synecological and democological research, allelopathically active weed compounds and scientific principles of phytoregulators development (V.G. Kozeko, N.P. Didyk, V.Y. Maryushkina, L.V. Orel);
- (xi). **Allelopathic processes during the development of woody and shrub plants** (the problem of accumulation of phytotoxic products in the environment for growing cucumbers and tomatoes by groundless method; allelopathic properties of some woody and shrubby plants used for landscaping; chemical nature of beech leaf inhibitors European and Japanese birch; allelopathic features of flowers and precipitation of woody and shrubby plants; phytocenotic characteristics of new introduced plant species (O.I. Dzyuba, V.M. Gaidamak, V.M. Oleksevich, V.V. Mitin, S.G. Kovalenko (125), S.I. Galkin);

(xii). **Allelopathic studies of fruit and berry plant species** (study of the allelopathic role of fallen leaves and root remains of apple and peach; study of ecological aspects of allelopathic after effects of edifiers of garden phytocenoses; study of allelopathic properties of wild plant chromatographs; soil extracts and species-specific allelopathic activity of bioassays with the use of cut peach shoots; elaboration of schemes of alternation of new fruit crops during their cultivation in orchards; study of allelopathic properties of multi-flowered olive (*Elaeagnus multiflora* Thunb.) (P.A. Moroz, I.I. Popivsky, V.P. Grakhov, I.Y. Osipova, E.A. Vasyuk, I.M. Grikun);

(xiii). **Allelopathic processes in agrocenoses of crops** (study of allelopathic role of alfalfa in cotton-alfalfa crop rotations; detection of changes in anatomical structure of flax plants and study of its biochemical changes in monoculture; development of biological method of flaxseed control) (L.P. Stepanova, O.V. Maistrenko);

(xiv). **Allelopathic features of cultivation of ornamental, aromatic and flowers** (scientific substantiation of introduction of higher plants in interiors of modern buildings taking into account their biological compatibility, sensory-aesthetic specificity and possibility of improvement individual parameters of human habitat, allelopathic features, phytoncide properties of begonias in industrial interiors, the problem of allelopathic properties of some plants of the umbrella family, study of biological features of some species of the filamentous family when grown in culture, study of allelopathic features of sage (*Salvia sclarea* L.); ecological bases of allelopathic interactions and after effects of aromatic plants in agrophytocenoses; study of allelopathic and biochemical features of species of the genus *Tagetes* L.; study of allelopathic properties of introduced species of the genus *Echinacea* Moench; study of agroecological and allelopathic properties of plants of the genus *Calendula* L.; allelopathic properties of aromatic plants of *Monarda didyma* L., *Dracocephalum moldavicum* L., *Hyssopus officinalis* L.; allelopathic features of plants of species of the genus *Lavendula* L. (V.V. Snezhko, B.M. Kaspari, N.I. Prutenskaya, L.Y. Garshtya, O.O. Ilyenko, G.A. Pobirchenko, L.D. Yurchak, S.P. Mashkovskaya, T.O. Shcherbakova, O.V. Mishchenko, S.A. Radioza, N.O. Hnatiuk, O.P. Yunosheva, A.Y. Bezmenov).

DISSERTATIONS

The Allelopathy Dissertations, Department of Allelopathy, National Botanical Garden M.M. Grishka NAS of Ukraine, Kiev were as under:

(i). **Natural phytocenoses:** (T.M. Filipovich (1966 – here and hereafter the year of Dissertation defence); G.E. Zhamba (1969); L.S. Akhov (2000); N.E. Ellanska (2003); L.S. Panova, V.A. Derevyanko, V.V. Osichnyuk);

(ii). **Main agricultural crops:** (N.I. Prutenskaya (1967); T.P. Bukolova (1973); Y.G. Kovalchuk (1974); L.I. Krupa (1983); E.A. Golovko (1985); T.S. Shroll (1990); L.V. Podoba (1994); O.V. Maidebura (1995); V.K. Puzik (2004); N.N. Dzyubenko, M.O. Panchuk, N.I. Petrenko, G.P. Bogdan, S.V. Petrenko, V.A. Derevyanko);

- (iii). **Soil:** (S.G. Leshenko (1971); L.S. Seredyuk (1971); S.O. Gorobets (1982); L.I. Krupa, K.S. Stefansky);
- (iv). **Weeds:** (V.G. Kozeko (1993); N.P. Didyk (2001); V.Ya. Maryushkina (1983; 2003); L.V. Orel (2004);
- (v). **Wood and shrub plants:** (V.M. Oleksevich (1971); V.V. Mitin (1973); V.M. Haydamak (1967); S.G. Kovalenko (1975); S.I. Galkin (1983); O.I. Dziuba (2001); N.A. Pavlyuchenko (2003); V.A. Derevyanko, V.K. Myakushko);
- (vi). **Traditional and new fruit crops:** (P.A. Moroz (1968; 1995); I.I. Popivsky (1974); V.P. Grakhov (1991); I.Yu. Osipova (2000) (151); E.A. Vasyuk (2004); I.M. Grikun);
- (vii). **Technical and fodder crops:** (L.P. Stepanova (1975); O.V. Maistrenko (1990); I.M. Pursiyanova);
- (viii). **Microflora:** (L.D. Yurchak (1971), G.P. Kushnir, T.S. Shroll, E.A. Golovko, O.Y. Kostroma, N.E. Ellanskaya);
- (ix). **Allelopathic interaction in closed ecosystems:** (T.M. Bilyanovskaya (1992); V.M. Haydamak, S.O. Gorobets, V.I. Kolosov, V.A. Derevyanko, Y.M. Yudin, L.O. Popovicheva, A.Ya. Bezmenov);
- (x). **Ornamental plants:** (V.V. Snezhko (1983); V.M. Caspari (1992); N.I. Prutenskaya);
- (xi). **Plants and space** (N.I. Prutenskaya, N.V. Zaimenko);
- (xii). **Medicinal, aromatic plants:** (L.Ya. Garshtya (1971); O.O. Ilyenko (1983); G.A. Pobirchenko (1988); S.P. Mashkovskaya (2002); T.O. Shcherbakova (2004), L.D. Yurchak (2002), A.Y. Bezmenov (2000).

Team leaders of allelopathic research: P.A. Moroz, L.D. Yurchak, E.A. Golovko. Besides the school of A.M. Grodzinsky, other eminent allelopathic scientists of the USSR were: A.Ch. Tambiev (247-251), M.V. Kolesnichenko (119-124), V.P. Ivanov (102-110), N.M. Matveev (135-138), D.D. Verdercvskii (261-263), I.N. Rakhtenko (130,166-179). These scientists did basic research on allelopathy on (i). Root secretions of plants, (ii). Role of volatile plant secretions and their environmental impact, (iii). Role of plants extracts on germination and initial growth of test cultures and cultures-acceptors. Later basic research was done in the field of forest allelopathy (I.N. Rakhtenko, M.V. Kolesnichenko) (119-124,166-179), allelopathy of mixed phytocenoses (V.P. Ivanov) (163), chemistry of allelopathic aspects of plants at physiological and cellular levels (V.D. Roshchina, V.V. Roshchina) (180,182,187). Ivanov developed the methodology to study allelochemicals of plant root secretions using radioactive isotopes. He reported the importance of factors (moisture, temperature, light) in detecting the interactions of root secretions and the role of accompanying microflora (109,110).

2. BIOGRAPHIES OF ALLELOPATHY SCIENTISTS (1880-1984)

During 1980-1990, numerous discoveries were made in Botany, Physiology, Ecology, Phytocenology and methods of identification of chemicals. **The allelopathy research in the post-Soviet era has almost stopped.**

2.1. Vladimir Nikolaevich Sukachov (1880-1967)

Soviet Geobotanist, Forester, Ecologist, Paleontologist and Organizer of science conferences, academician of USSR Academy of Sciences, He introduced 'Biogeocenosis' and developed biogeocenology.

Early life and education (146,157,292): Born on May 26, 1880 in village Aleksandrovka (Zmievisky district, Kharkov province). In 1898 he passed School and joined the Forestry Institute, St. Petersburg and worked with G.F. Morozov Forester and Botanist. After graduation, he joined Department of Botany. In 1905 he taught agricultural courses at the St. Petersburg (Kamennooostrovsky).

Professional life and contributions to allelopathy: He did research in Botany, Geography, Soil science, Geology, Biosphere. He was Professor, Leningrad Forestry Academy, Moscow Forestry Institute, Leningrad and Moscow Universities. He was Director, Institute of Forestry, USSR Academy of Sciences in Moscow and Krasnoyarsk.



Figure 1. Vladimir Nikolaevich Sukachov.

Table 3. Chronology of main events

Dates	Events
1882	Born on May 26, 1880 in the village of Aleksandrovka, Zmievisky district, Kharkov province, Russia
1898	Passed from the Kharkov school and entered the St. Petersburg Forestry Institute
1902-1905	Assistant, Forestry Institute St. Petersburg
1905-1907	Scientific internship in Germany
1911-1919	Taught Agricultural Courses at the St. Petersburg
1912-1918	Botanical Museum, the Russian Academy of Sciences
1924-1926	Head, Main Botanical Garden, USSR Academy of Sciences
1931-1933	Head, Department of Geobotany, Botanical Institute, USSR Academy of Sciences
1934	Awarded the degree of Doctor of Biological Sciences
1919-1941	Head, Department of Dendrology and Plant Systematics of the Forestry Institute.
1941-1943	Head, Department of Biological Sciences, Ural Forestry Institute, Sverdlovsk
1943	Elected full member, USSR Academy of Sciences, Department of Biological Sciences (Botany, Phytocenology, Biogeocenology, Phytopathology)

1944-1948	Professor, Moscow Forestry Institute, Head Department of Dendrology and Plant Systematics
1946-1958	Editor-in-Chief, Bulletin Moscow Society of Nature Testers (1948-57), Botanical Journal (1946-58)
1946-1953	Professor, Faculty of Geography, Moscow State University, Head Department of Botanical Geography (1951) / Department of Biogeography (1953)
1944-1958	Director, Institute of Forestry and Timber (since 1962)
1959-1962	Head, Forestry Laboratory, USSR Academy of Sciences
1955-1967	President, Moscow Society of Naturalists
1964-1966	Head, Laboratory of Biogeocenology, Botanical Institute, USSR Academy of Sciences
1967	Died on February 9, 1967 in Moscow

He developed new science of Biogeocenology. He did research on allelopathy in phytocenology. In 1934, he did phytocenological studies of the relationship between plants in natural cenoses. During 1935-1940 he studied the biological and ecological features of species in natural and artificial (in nurseries) conditions. He formulated the basic principles of sustainability, ecological stability of phytocenoses (245). He developed the concept of plant vitality, based on the chemical interactions between plants at the level of soil nutrition and terrestrial plant secretions (246), biological dominance of plants and their mutual influences (243,244). There are chemical interactions between plants, depending on the environmental conditions and level of their stress. He also formulated the basics of self-allelopathic incompatibility with size of individuals of one specie and their phenological development, depending on population density of specie, called 'Sukachov's rules'. He developed the scheme of plant interactions in the phytocenosis (Figure 2), based on the mechanisms of mutual influence of plants.

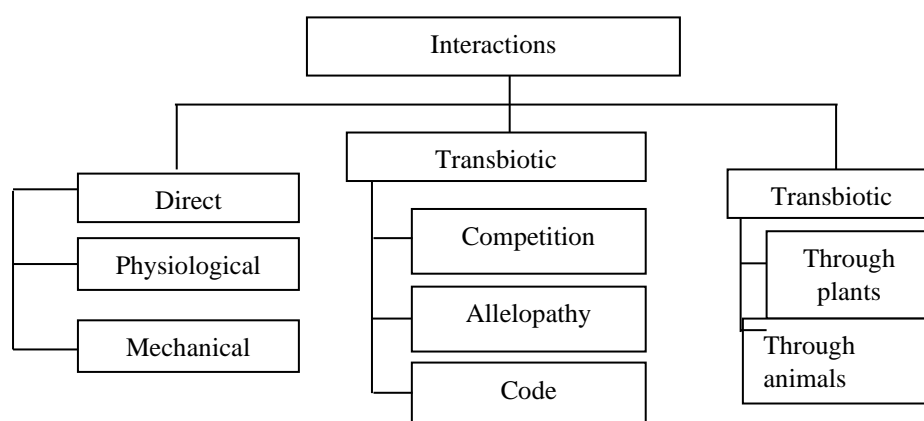


Figure 2. Scheme of plant relationships in phytocenosis for V.N. Sukachov (244).

Sukachov (244,246) proposed to divide all plant interactions in 3-groups: (i). Contact interactions that occur when plants are in full contact, (ii). when they touch, grow

together and, (iii). when one plant penetrates the body of another. This can be parasitism and semi-parasitism, accretion of roots, the influence of lianas, overlapping with branches, or pressure of rhizomes and roots during their growth. Transbiotic relationships arose due to changes in the conditions of existence of cohabitants by plants (competition, release of various substances by plants into their environment, formation of dead litter. Transbiotic relationships arising due to the indirect influence of one organism on another through a change in the conditions of existence of a third organism. According to this scheme, allelopathy is indirect interactions of plants through changes in the environment. Allelopathically active substances are released by plants into the environment, accumulate and change the environment, and these changed the life of other plants. Thus, the scientist attributed allelopathy to transbiotic interactions (indirect effects of some plants on others through third organisms).

Scientists have laid the foundations to study the phytogenic fields, one areas of study of allelopathic relationships of plants in the cenosis (244). It was proved that electromagnetic oscillations generated by one plant induce an electromagnetic field in a neighboring plant, which contributes to the mutual adjustment of biorhythms of a given plant and vibrational dynamics of environmental factors and enhances its material-energy exchange processes with the environment, accelerating its growth and development.

He also made significant contributions to the study of allelopathy based on plant interaction in forest cenosis of various types, and outlined the role of plant life in phytocenoses formation in soil and on surface of dead organic plant matter (precipitation), the formation of a special microclimate within the phytocenosis. Such effects of plants on each other are also related to transbiotic interactions, as they occurred through changes in the abiotic conditions of plant existence. Scientists studied the formation of cenosis and type of competition (243,244).

PUBLICATIONS (Russian)

Authored more than 600 publications on Biogeocenology and Phytocenology, Swamp Science, Paleobotany, Flora and Fauna of various regions of the USSR. Only major research papers and monographs have been listed.

Books/Monographs

- (i). Sukachov, V.N. (1931). *Guide for Study of Forest Types*. 301 pp. State Publishing House of Agriculture and kolkhoz-cooperative literature, Moscow (Russian).
- (ii). Sukachov, V.N. (1934). *Dendrology With the Basics of Forest Geobotany*. 614 pp. Goslestekhzdat: Leningrad (Russian).
- (iii). Sukachov, V.N. (1972). *Selected works: Vol. 1: Fundamentals of Forest Typology and Biogeocenology*. 419 pp. Leningrad, Naukova (Russian).
- (iv). Sukachov, V.N. (1973). *Selected works: Vol. 2: Problems of Bog Science, Paleobotany and Paleogeography*. 352 pp. Leningrad, Naukova (Russian).
- (v). Sukachov, V.N. (1975). *Selected works: Vol. 3: Problems of Phytocenology*. 543 pp. Leningrad, Naukova (Russian).

Research Papers

- (i). Sukachov, V.N. (1925). Experimental phytosociology and its tasks. *Notes, Leningrad Agricultural Institute* **2**: 174-86 (Russian).
- (ii). Sukachov, V.N. (1927). On the question of the struggle for existence between biotypes of the same species. In: *Jubilee Collection dedicated to I.P. Borodin* pp. 195-219. Russian Botanical Society, Leningrad (Russian).
- (iii). Sukachov, V. N. (1928). Principles of classification of the spruce communities of European Russia. *Journal Ecology* **16**(1): 1-18 (Russian).
- (iv). Sukachov, V.N. (1934). What is a phytocenosis?. *Sovetskaya Botanika* **5**: 4-18 (Russian).
- (v). Sukachov, V.N. (1935). Experimental study of interbiotypic struggle for existence in plants. *Works of Peterhof Biological Institute* **15**: 69-86 (Russian).
- (vi). Sukachov, V.N. (1941). Influence of intensity of struggle for existence between plants on their development. *Reports, USSR Academy of Sciences* **30**(8): 752-755 (Russian).
- (vii). Sukachov, V.N. (1942). The development in phytocenology. *Sovetskaya Botanika* **1-3**: 5-17 (Russian).
- (viii). Sukachov, V.N. (1944). Principles of genetic classification in biocenology. *Journal of Total Biology* **5**(4): 213-227 (Russian).
- (ix). Sukachov, V.N. (1945). Biogeocenology and Phytocenology. *Doklady Academy of Sciences of USSR* **47**(6): 447-449 (Russian).
- (x). Sukachov, V.N. (1949). Relationships between 'Geographical landscape' and 'Biogeocenosis'. *Questions of Geography* **16**: 45-60 (Russian).
- (xi). Sukachov, V.N. (1959). Experimental study of plant relationships. *Bulletin MOIP*. **64**(4): 35-46 (Russian).
- (xii). Sukachov, V.N. and Dylisa, N.V. (1964). Biogeocenosis-interactions of animate and inanimate nature on the Earth's surface: The relationship between the concepts of "Biogeocenosis", "Ecosystem", "Geographical landscape" and "Facies" In: *Foundations of Forest Biogeocenology* (Ed., V.N. Sukachov) pp. 5-49. Naukova, Moscow (Russian).
- (xiii). Sukachov, V.N. and Zonn S.V. (1961). General principles to study forest types. In: *Methodical Instructions for Studying Forest Types. 2nd ed* pp. 9-75. Publishing house, of the Academy of Sciences of the USSR, Moscow (Russian).

2.2. Mykola Hryhorovych Kholodny (1882-1953)

Outstanding Botanist, Physiologist, Microbiologist, Ecologist, Associate Professor (1912), Doctor of Botany (1926) and Academician, USSR Academy of Sciences (1929), Honoured Scientist of USSR (1944).

Early life and education (191,192): He worked as Botanist, Plant Physiologist, Microbiologist and Soil scientist. He was born in Tambov on June 22, 1882. In 1900, passed High School with gold medal and entered the University of St. Vladimir, Kiev, graduating with honors in 1906.

Professional life and contributions to Allelopathy (6,35,263): He began his research in 1902 in Department of Anatomy and Physiology of Plants. In 1912 he received

Master's degree in Microbiology. During 1912-1915 he developed the basic methodology of microbiological soil research, prepared a practical course in Microbiology and studied the thermophilic denitrifying soil bacteria. In 1919 he received Master's degree in Botany. In 1920, he was appointed Professor, Kiev Institute of Public Education. In 1933, he established Biology Faculty at University of Kiev, with independent Department of Microbiology. He studied the soil microflora and became famous scientist in field of Plant Physiology and Soil Microbiology. He also did research on influence of metal ions on irritability in plants and on the physicochemical properties of protoplasm.



Figure 3. Mykola Hryhorovych Kholodny.

In 1924, at Botanical Station, Kiev, Dnieper, he studied the hormonal phenomena in plants, their growth regulation, movement in higher plants, mutual influence of plants in cenoses through various types of plant secretions and microflora of water.

Table 4. Chronology of main events

Dates	Events
1882	Born on 22 June, 1882 in Tambov, Tambov province, Russia
1900-1906	Student St. Volodymyr's University, Kiev
1912	Received Master's Degree (Microbiology)
1912-1915	Developed methodology of Microbiological soil research, prepared practical course in Microbiology
1919	Master's Degree (Botany)
1920	Professor Institute of Public Education, Kiev
1924	Study of hormonal phenomena in plants
1925	Corresponding Member, USSR Academy of Sciences
1929	Full member, USSR Academy of Sciences
1934-1945	Developed the hormonal research in plants relationships in cenoses
1939	Published monograph 'Phytohormones'
1945-1949	Head, Department of Plant Physiology and Ecology, Institute of Botany
1949-1953	Developed 'Hormonal Theory of Tropisms and Chemistry of Plant Interactions'
1953	Expired on 4 May, 1953

In 1925, he was elected corresponding member, USSR Academy of Sciences and in 1926 he was awarded the degree Doctor of Botany. In 1929, he established Department of Plant Physiology, USSR Academy of Sciences. During 1934-1945, he studied the effects of synthetic substances on plant morphogenesis. From 1945-1949, he worked in Department of Plant Physiology and Ecology, Institute of Botany. He died on May 4, 1953 in Kiev.

In studies on the physiology of growth, he concluded that the hormones control the plant growth, developed the doctrine of Phytohormones (115,116) and published the monograph 'Phytohormone' (1939). He developed methods to study the microbial population in soils and reservoirs ecological and allelopathic research in microbiology (112). He was father of Soviet science on 'Chemical Interactions of Plants and Soil Microbiology' (117). He studied the problem of volatile organic compounds in atmosphere and their biological role (112). He contributed to the development of Ecological and Biological Soil Science (111). He taught Botany, Anatomy, Histology, Phytology and Phytoembryology of plants and Microbiology. He developed a biotest to identify volatile secretions in seeds and soil. Later he studied volatile plant secretions, their classification, mode of action and physiological significance in natural ecosystems (159,205).

PUBLICATIONS (Russian)

His more than 200 researches were on Plant Ecology, Physiology and Anatomy problems of natural science, Microbiology and Soil Science. Only major research papers and monographs have been listed.

Books/Monographs

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- (ii). Kholodny, M.G. (1953). *Iron Bacteria*. 224 pp. USSR Academy of Sciences, Moscow (Russian).

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- (xii). Kholodny M.G. (1982). *Selected Works. Academy of Sciences of the Ukrainian SSR. Institute of Botany*. 444 pp. Naukova Dumka, Kiev. (Russian).

2.3. Sergei Ivanovich Chernobrivenko (1899-1967)

He developed coenotic directions of allelopathic research in laboratory and field conditions. He was born 1899 in Novokhopirsk, Voronezh region. In 1929 he graduated as Agronomist from Moscow Agricultural Academy, Timiryazeva.

Professional life and contributions to allelopathy (4,5): During 1935-1964, he developed varieties of different crops. During 1960-1964 he was Head, Department of Crop Production, Agricultural Institute Dnipropetrovsk (Ukraine). He analyzed secretions of plants and studied their allelopathic interspecific interactions between species (Figure 4), classified those mutually or unilaterally promote or inhibit mutual growth. He wrote book on allelopathy but was not translated to English (5,27). His allelopathy research began in 1948, at Experiment Station, Sinelnikovskaya (Dnipropetrovsk region, Ukraine). He investigated the interactions between various combinations of 30 crops. His work was published in 1956 in book *'The Biological Role of Plant Excretions and Interspecies Interactions in Mixed Crops'* and was translated to Chinese in 1961. Chernobrivenko recognized that allelopathic interactions includes all possible interactions between a pair of plant species. He reported 'friendly' relationships between following plants (Figure 4).

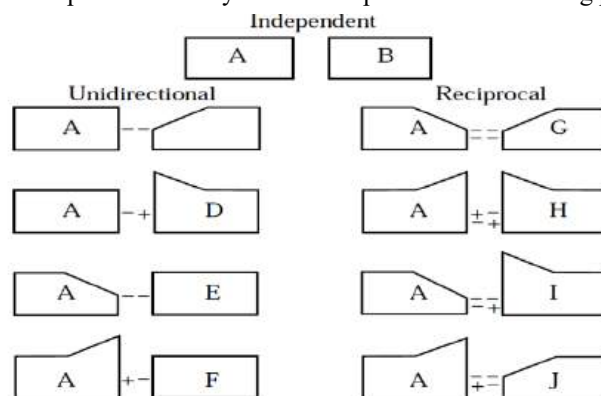


Figure 4. Chernobrivenko's scheme of interactions between species (27).



Figure 5. Sergei Ivanovich Chernobrivenko.

Table 5. Chronology of main events

Dates	Events
1899	Born 1899 in Novokhopirsk, Voronezh region Russia
1924-1929	Agronomist, studied in Moscow Agricultural Academy, Timiryazeva
1935-1941	Soybean breeding, All-Union Research Institute of Maize (Dnepropetrovsk, Ukraine)
1943-1944	Director, Research Station, Krasnograd
1944-1966	Head, Department of field crops, All-Union Research Institute of Maize)
1956	Monograph ' <i>Biological Role of Plant Excretions and Interspecies Interactions in Mixed Plantings</i> '
1960-1964	Head, Department of Crop Production, Agricultural Institute, Dnipropetrovsk (Ukraine)
1967	Expired, 1967

He did similar allelopathic research on 40-trees and shrubs to assess their allelopathic potential.

Table 6. Allelopathic relationships of plant species (31)

Donor Plant	Harmful effects on Recipient plants	Donor Plant	Beneficial effects on Recipient plants
Barley	Alfalfa, chickpea, bean	Bean	Potato, tomato, eggplants, gray mustard, flax, sunflower, corriander, pumpkin, melon, watermelon, cucumber, pea
Bean	Spring wheat	Castor	Gray mustard, chickpea, bean, corn
Buckwheat	Corn	Chickpea	Mustard, camelina, spring wheat, barley, flax, hemp
Chickpea	Eggplant, castor oil plant, pumpkin, cucumber, melon, watermelon, beans, sunflower, corn	Corn, castor	Bean, chickpea
False flax	Flax	Hemp	Sunflower

Gray mustard	Castor oil plant, hemp, chickpeas,	Kenaf	Hemp, castor
Hemp	Kenaf, chickpeas, beans	Lentil	Alfalfa
Lupine	Potatoes, tomatoes	Lettuce	Radish
Oat	Perennial lupine, blue narrow-leaved lupine, pea	Lupine	Pea
Pumpkin	Castor	Onion	Chicory
Rye	Winter wheat	Pea	Potato, alfalfa
Spring wheat	Hemp, camelina, mustard, flax, anise	Potato	Barley
Sunflower	Corn	Spring wheat	Melon, watermelon, soybean, sesame, castor, pumpkin,
Tomato	Cucumber	Sunflower	Hemp
Turnip, radish	Tomato	White mustard	Pea

Based on these studies, the concept of allelopathic regime in cenosis was formulated (31). Some plants of phytocenosis have allelopathic potential due to edificators (Main components of phytocenosis for sustainable interaction in plant ecosystem) and dominants (plant species which suppress other species to change the structure of plant community), because they predominate in phytomass, transform the environment (27).

PUBLICATIONS (Russian): 40.

Only major research papers and monographs have been listed.

Books/Monographs

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Research Papers

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2.4. Boris Petrovich Tokin (1900-1984)

Early life and education: Boris Petrovich Tokin was born on 21 July, 1900 in village Grushevskaya, Saratov region, Russia. He became a student of Medical faculty, Moscow State University in 1923. Later he shifted to Physico-chemical faculty, Biology Department and specialised in Embryology and got M.Sc. degree in 1929. Thereafter, he worked as Zoologist in Moscow Zoo and then became a post-graduate student in Biology Institute, Soviet Academy of Sciences, Moscow. He obtained his Ph.D. degree in 1931, specialising in animal cells and tissues. Working with ruptured plant tissues, he found that volatile compounds released from them have antimolusc and antimicrobial activity and termed them as *Phytoncides*. These results were presented at various Conferences viz., Moscow Society of Naturalists (1928), All Union Congress of Zoologists, Kiev (1929) and international Congress on Cytology, Amsterdam (1930) and published in *Biologische Zentralblatt* (1930) (126,127).

Professional life and contributions to allelopathy: In 1931, Boris Tokin became Head, Biology Institute and member Editorial Board of *Biology Journal*. In 1935, he received degree of Doctor of Science and in 1936, he was appointed Professor at Tomsk University. He studied the Medicinal plants releasing phytoncides with the physicians in War hospitals. Using phytoncic features of garlic, onion, tree leaves etc. his team prepared new drugs (252). He popularized the idea that plants also produce biologically active, volatile substances, that can affect all living organisms including growth of microorganisms. In 1942, he published a monograph '*Bactericides of Plant Origin (Phytoncides)*' in Russian.



Figure 6. Photograph of Boris Petrovich Tokin.

Tokin received less credit as a pioneer in Allelopathy, because his early books reported the effects of inhibitory root exudates on seed germination. On the other hand, he said that inhibitors prevented the seeds from competition, until the environment was favourable for germination and success of species (254). Secondly, the 1951 edition of Tokin's Russian book on Phytoncides was improved and translated into German, and published in 1956 as *Phytonzide* (253). Thereafter till 1984, he worked on phytoncides at Institute of Experimental Medicine, Medical Academy of Sciences, Leningrad (1945-55) and as Head, Department of Embryology, Leningrad State University. He was awarded the

state Prize for discovery of phytoncides in 1950. He also demonstrated the major role of phytoncides as ecological factors in allelopathy (Figure 7) (256). He organized conferences and symposium on phytoncides. He made phytoncides an interesting area of research for agronomists and foresters and published 6-Monographs. He died on 16 September, 1984.

Table 7. Chronology of main events

Dates	Events
1900	Born on 21 July, 1900 Village Grushevka, Atkarskii volost, Saratov region, Russia
1923-1929	Student Medical Faculty, \ Biology Department, Moscow State University
1928-1930	Discovered substances with phytoncicidic properties in plant excretions
1931	Received Ph.D. Degree
1931-1936	Head, Biology Institute, USSR Academy of Sciences, Moscow
1936-1945	Professor, Department of Animal Development and Rector, Tomsk State University, Siberia
1942	Monograph <i>Bactericides of Plant Origin (Phytoncides)</i> published
1941-1945	Studied characters of Medicinal plants releasing phytoncides and formulated new drugs
1945-1955	Institute of Experimental Medicine, Medical Academy of Sciences, Leningrad
1948	Book <i>Biological Role of Phytoncides</i> released, later translated to German language, Published 1956.
1949-1984	Head, Department of Embryology, State University, Leningrad
1950	Received State Award for 'Discovery of Phytoncides'
1957-80	Book <i>Solubrious Poisons of Plants: Story of Phytoncides.</i> published in 3-volumes
1984	Expired on 16 September, 1984

Currently the phytoncides are vigorously being studied in several research centres in Russia and Ukraine to prepare numerous natural drugs from phytoncicidic plants. The doctrine of phytoncides as allelopathic substances was developed in researches of his followers (2,39,70,71,260-262,285).

Table 8. Classification of Phytoncides (257).

A. Types of Phytoncides

1. Air phytoncides (Volatile fractions of phytoncides)
2. Soil phytoncides (Liquids and volatiles produced by underground parts of plants)
3. Aquatic phytoncides (Produced by aquatic plants)

B. Excretory and Non-Excretory phytoncides

Non-excretory phytoncides	Excretory phytoncides
1. Natively active	1. Volatile fractions
2. Extracellular active	2. Liquids

C. Phytoncides effects on Recipient plants and organisms

A. Phytoncides: Bactericidal, fungicidal and protistocidal produced by higher and lower plants. Phytoncides that stimulate the vital activity of certain groups of organisms	B. Phytoncides toxic to insects, mites, worms and other macroorganisms	C. Phytoncides (from higher and lower plants), stimulatory/ inhibitory to germination of pollen, growth and development of other plants
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PUBLICATIONS (Russian)

His researches were published in Russian and many were translated into German. Only major research papers and monographs have been listed.

Books/Monographs

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3. CONCLUSIONS

The allelopathic Schools of former USSR during the period 1880-1984 founded the new fundamental directions of allelopathic plant interactions. These schools studied the phytocoenological plant communities and their systematic classification, levels of organization and their interactions. These provided the basis for development of theories on soil rhizosphere interactions of plant organisms, phytogenic fields, biochemical interactions of plants through transpiration and root secretions. These scientists also developed the field of chemical interactions of plants, now used in allopathic research by the world community. These include the concepts of phytoncides, agrophytocenology, life strategies of natural and artificial plant agrophytocenoses, plant interactions resulting in dominance and phytoadaptability. These scientists developed systems for biotesting of allopathic compounds in laboratory and field and formulated the fundamental principles of plant allelopathy and agrocenoses.

DECLARATION OF COMPETING INTERESTS

The authors declare that they have no competing financial interests related to the publication of this manuscript. The research was conducted independently, free from any conflicts of interest that could have biased the findings.

AUTHORS' CONTRIBUTIONS

Both authors approved and finally draft of manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest. All authors agree to publish it.

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