Temperate Crop Science and Breeding

Ecological and Genetic Studies

Editors

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Anatoly I. Opalko, PhD | Larissa I. Weisfeld, PhD

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LIST OF ABBREVIATIONS

ANOVA	analysis of variances
ApMV	apple mosaic virus
BCP	bioclimatic potential
BEA	beef-extract agar
BiOECOFUNGE-1	antipathogenic biopreparations based on mushrooms components and carries of plants
BSAA	Belorussian state agricultural academy
BVG_i	breeding value of a genotype
CA	congenital anomalies
CC	critical concentration of every element
Cd	cadmium
cGy	cantiGrey
ChA	chromosomal aberrations
cM	cantimol
cm	centimeter
CMD	congenital malformations of development
CO	carbon monoxide
Co	cobalt
CO_2	carbon dioxide
Cs	cesium
Cu	copper
CV	coefficient of variation
cwt	centner, hundredweight
DAS-eA	double antibody sandwich-enzyme-linked immunosorbent assay
DIECA	sodium dietildytiocarbomat
DSS	dry soluble substances
DUS	distinguishability uniformity stability
e.g.	exempli gratia (lat.)
EIV	ellenberg indicator values
ELISA	enzyme-linked immunosorbent assay

EQ.	equalent
Etc.	et cetĕra (lat.)
eV	electronvolt
FAO	Food and Agriculture Organization of the United Nations
FC	form coefficient
FDR	field drought resistance
GAA	general adaptive ability of a genotype, characterizes average value of a trait in various environmental conditions
GDV	gas discharge visualization
GENAN	genetic analysis (computer software)
GPS	Global Positioning System
HC	hydrothermal coefficient
Hd	soil moisture
$HgCl_2$	mercury (II) chloride
HTC	hydrothermal coefficient
i.e.	Id est (lat.)
K	potassium
LAR	leaf area ratio, the ratio of total leaf area to stem or twig mass
LSD_{05}	least statistical distinction = least significant difference at $p<0.05$
LWR	leaf weight ratio, ratio of leaf mass to total plant mass
MAC	maximum allowable concentrations
Mo	molybdenum
MPa	megapaskal
MPC	maximum permissible concentration
MS	Murashige–Skoog nutritive medium
N	nitrogen
NAAS	National Academy of Agrarian Sciences
NaOCl	sodium hypochlorite
NAS	National Academy of Science
$NaS_2CN(C_2H_5)_2$	sodium diethyldithiocarbamate
$NaSO_3$	sodium sulfur

NDP	National Dendrological Park
NFE	nitrogen-free extract
NPK	fertilizer: nitrogen, phosphorus, and potassium
NPP	net photosynthesis productivity
NSC	National Science Centre
OAR	obstetric anamnestic record
P	phosphorus
PABA	para-aminobenzoic acid
PAGe	polyacrylamide gel
Pb	lead
PEG	polyethylene glycol (used as osmotic)
pH	hydrogen ion concentration
PNRSV	prunus necrotic ringspot virus
QTL	quantitative trait locus
RA	regenerant obtained of aluminum-acid media
RAC	roughly allowable concentration of every element
Rc	soil reaction
RFLP	restriction fragment length polymorphism
RNA-asa	ribonucleasa
RNO – Alania	Republic of North Ossetia – Alania
ROS	Reactive Oxygen Species
RRG	Relative Root Growth
RTI	root tolerance index, is counted as average root length in test treatment divided by root length in control treatment
SA	spontaneous abortion
SAA	specific adaptive ability of a genotype, characterizes a deviation from *GAA* in the exact environment
SB	stillborn
SLA	specific leaf area, one-sided area of a fresh leaf, divided by its oven-dry mass two-way
SNP	single nucleotide polymorphisms
SOD	superoxide dismutase
Sr	strontium

SSD	smallest significant difference
two-way ANOVA	ANalysis Of VAriance between groups with two factors
UPOV	International Union for the Protection of New Varieties of Plants = distinctness, homogeneity, stability = distinctness, uniformity, stability
VIR	N.I. Vavilov Research Institute of Plant Industry
WPI	index of water pollution
WSFO	concentration of water-soluble fractions of oil
X-ray exposure	X-ray irradiation, X-irradiating
Zn	zinc

LIST OF SYMBOLS

$\sqrt{H_1 / D}$	average degree of dominance by all heterozygous loci
°X	degree Celsius
2n	diploid chromosomal set
$AgNO_3$	silver nitrate
Al	aluminum
Al^{+++}	ion of aluminum
Al_aAl_a	dominant alleles of aluminum resistance in oats
al_aal_a	recessive alleles of aluminum resistance in oats
b_i	linear regression coefficient
Bq/kg: kBq/m^2	coefficient of transition of radionuclide from soil to plants
c/ha	center/ha, hundredweight
$C_2H_5(OH)$	ethyl alcohol
$C_6H_8O_6$	ascorbic acid
$C_9H_9HgNaO_2S$	(Thiomersal) mercury((o-carboxyphenyl)thio) ethyl sodium salt
Ca^{++}	ion of calcium
F	component of variability reflecting a direction of dominance on the average on a number
F_1, F_2, F_3, F_4	generations of organisms from first to fourth and so on
g	gram
G_0	phase 0 of the mitotic cycle
G_1	presyntetic phase of the mitotic cycle
G_2	postsyntetic phase of the mitotic cycle
H^+	hydrogen ion
H_1, H_2	components of variability caused by dominante effects

ha	hectare – is area unit that equal to 10,000 square meters
kBq/m^2	kilo Becquerel per square meter
KCl	potassium chloride
K_d	phytocoenosis destruction index
kg	kilogram
Kg/ha	kilogram/hectare
KH_2PO_4	potassium dihydrogen phosphate
km	kilometer
l	liter
mg	milligram
Mg/kg	milligram/kilogram
Mg^{++}	ion magnesium
mkg	microgram
mkl	microliter
ml	milliliter
Mcg	microgram
ml_1–ml_0	difference between average mean for parents and average
mln	million
Mm	micromoles
mm	millimeter
mm per year	millimeters per year – atmospheric fallouts amount
M	gram-molecule
$M_1 - M_7$	generations of mutants from first to seventh
n	haploid chromosomal set, chromosome complement
NH_4^+-N	ammoniacal form of nitrogen fertilizer
NH_4NO_3	ammonium nitrate
NH_4NO_3	mixed form of nitrogen fertilizer
NO_3^-N	nitric form of nitrogen fertilizer
$P_{30}K_{30}$	fertilizer: phosphors, potassium
psc.	pieces
r	coefficient of pair correlation
R	Roentgen

R_4 and R_5	fourth and fifth generation of regenerants
S	phase synthesis of DNA of the mitotic cycle
S_{gi}	relative stability of genotype
sm	centimeter
Sx	mean arithmetic error
Sx, % –	the relative mean arithmetic error
t	ton – is mass unit, that equal to 1000 pounds in the units
t/ha	ton/hectare
t_{05}	criterion of Student
th. t	thousand tones
Tr	nutrient content in the soil
ts	technical system
urc	units of regeneration coefficient
V	coefficient of variation
Xav	the average value of the characteristic
Xmax	maximum value of the characteristic
Xmin	minimum value of the characteristic
y-axis	axis of ordinates
Y_{dr}	yield in drought conditions
Y_{fav}	yield in favorable conditions of growth
Y_{min}, Y_{max}, Y_{aver}	minimum, maximum and average productivity of a variety

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PREFACE

Survival of the individuals of *Homo sapiens* L., as well as of the species as a whole, since prehistoric times was conditioned during millenniums by the success in hunting on wild animals and in gathering of edible parts of wild plants. Only a little more than 10 thousands year ago, when humans in different parts of the world started cultivation of plants and domestication of animals, our ancestors considerably decreased their dependence on fortuitousness due to consequent *agricultural revolution spread*, which allowed producing more food with smaller physical costs. Namely primitive *breeding*, as *selection* of the best specimens from extremely *heterogeneous* populations of wild animals and wild plants, unconsciously applied by ancient humans, provided possibilities of the *animal husbandry* and *field-husbandry* development in the remote past and, when taking more advanced modern forms, provided food supply of continuously increasing human population of the planet.

However, although a field, fully sowed with agricultural crops, gives the possibility to feed more people then forest, where edible plants occur separately, and a herd of *cattle* can provide more mouth to feed than can bag permanently nomadic hunter, further spread of Agricultural revolution brought up to the mankind new challenges unknown scent agriculture.

The possibility of population food supply under considerably smaller amount of farm workers provided labor resources to the mankind for the development of industry and a set of branch not related with the production of material goods. At the same time, enormous plants and factories, megalopolises, as well as giant orchards, enormous cattle-breeding farms and monocultural fields of several thousands hectares, the continuous cultivation of corn, sunflower, rape or other highly remunerative culture became source of permanent pollution of human habitat. Because of human economic activity the environment is changing more and more under permanently increasing anthropogenic impact, which reaches threatening scale in the conditions of the new globalization wave in 21st century, which swept over much of the developing world and many countries, which kept until recent time traditional agriculture. The planetary ecosystem, which was formed and evolved very slowly during centuries, is now exposed to the destruction in the past unknown.

The pages of this book are devoted to the analysis of processes affecting atmospheric, water, soil, mineral and other natural resources, their effect on human gene pool, as well as to the search of agricultural methods in stress conditions of pollution under rational use of recent achievements in plant breeding.

—*Anatoly I. Opalko*

INTRODUCTION

This new collection covers a wide variety of research on the ecological aspects of crops growing under stress conditions due to atmospheric changes and pollution and the impact on both plant and human health. The book provides research that will help to find ways to overcome adverse abiotic environmental factors and unfavorable anthropogenic pressures on crop plants, which also eventually impact human health.

This book is divided into six parts, united by common ideas: to finding ways to overcoming as of adverse abiotic environmental factors as and unfavorable anthropogenic pressures on crop plants and eventually on human health.

Science as the special kind of human activity has its own features that attract the intellectual elite of society. Science is characterized by continuity in reception, processing and generalization of knowledge. Therefore, scientific schools are formed; pupils continue work of the teachers. So, the chapters given by the scientist are already having popularity, which theoretically generalize the previous experience, and original experimental works of their colleges and pupils—post-graduate students, students, etc. These scientists work in the different institutes, different cities and countries, but the desire unites them to receive new knowledge and to share them with all interested people unites them.

Science develops both at regional and national levels. At the same time, regional scientific discoveries are part of a global science. As well as Vysotsky's songs attracted Finnish, Swedish, French performers and listeners, so scientific achievements can be understood and applied in different countries.

The authors invested maximum efforts in order to make the collection presented the appreciable contribution to development of a biological science.

Geneticists and breeders are creating new cultivars and hybrids of crops; thus, greatly expanding the range of source material.

Readers are invited to the results of studies from leading experts in the fields of biology, genetics, breeding of crops, taking into account of climatic and environmental changes.

The main agricultural crops like cereals, fodder crops, and horticultural plants are studied in various ecological and climatic conditions.

The book presents the works of leading scientists from different regions of Russia, Ukraine, and Belarussia that were carried out in contrasting environmental conditions. These works focuses on the impact of human activities on the environment, health, and status of the gene pool of the population in modern conditions.

Plant communities, interaction plant–soil–plant, ways of using plants as anticancer drugs and other important problems of nature management are examined.

Part I is titled "Plant Breeding Under Adverse Conditions of Acid Soils" and consists of seven chapters. The research of the ecological aspects of crops growing on acid soils of European-North Russia are presented in part I. In studies of the North-East Agricultural Research Institute and Vyatka State Agricultural Academy, Kirov, Russia, great attention is paid to generalization of studies conducted in various soil-climatic conditions of the country. The authors' opinions on different discussion problems are shown. These problems include seasonal and profile dynamics of elements of soil acidity; role of genetic and agronomical approaches in improving of plant productivity; using of methods of classic breeding; and biotechnology in creation of stress-tolerant cereal cultivars. Comprehensive analysis of the genetics and breeding of cereal crops was obtained with participation of specialists in the field of soil science (L. N. Shikhova, DSc), phytopathology (T. K. Sheshegova, DSc), plant physiology (E. M. Lisitsyn, DSc), tissue culture (O. N. Shupletsova, PhD), and plant breeding (G. A. Batalova DSc; I. N. Shchennikova, PhD). In the presented articles, the authors' opinions on different discussion problems are shown. These problems include seasonal and profile dynamics of elements of soil acidity; role of genetic and agronomical approaches in improving of plant productivity; and using of methods of classic breeding and biotechnology in creation of stress-tolerant cereal cultivars.

Part II is titled "Horticultural Crop Science" and consists of four chapters. Global trends on the market of horticultural production are characterized by stable growth of unsatisfied demand, which formed as a result of increasing consumption of fruits and berries, first of all in the states of European Union, Northern America, Japan, and other developed countries of the northern hemisphere. Now considerable changes in the nutrition structure in favor of fruits and berries is taking place in these countries. Apples, plums, apricots, raisins, nuts and other fruits and berries are more and more introduced not only as fruit addition to traditional vegetable salads, but are also added to soups, meat and fish dishes and are used in the baking not only of pastry and buns, but also of rye bread. Consequently, the states of European Union, Northern America, and Japan, in spite of high volumes of domestic production, belong to the biggest importers of fruits and berries in the world.

The analysis of fruits and berries production supply of the population of Ukraine shows its considerable deficit. Under science-based annual consumption norm, which amounts in the climatic conditions of the temperate climate zone 82 kg fruits and berries per capita of Ukraine population, their average production is 29–42 kg only. In contrast, in Spain this indicator exceeds 400 kg, in Italy and Moldova it approaches to 300 kg, and in Greece it exceeds 300 kg fruits and berries per capita. Even higher deficit is in berries, which production per capita in Ukraine is 3.4 kg under physiological norm of consumption for this region about 10 kg. At that a high inter-regional diversity of consumption level of horticultural production is observed in the country.

Annually Ukraine imports 15–20 kg of fruits and berries per capita, which provides together with domestic production about 70% of mean demand. Of that, under two million tons of total yield of horticultural products in Ukraine the portion of berries does not exceed 1.5–2.0%, whereas in the neighboring Poland, where total yield of fruits and berries reaches almost three and half million tons, namely berries, amount to 15–20%. The soil and climatic conditions of Ukraine are much more favorable for horticulture than in Poland or other neighboring countries. Consequently, it is necessary to perform in Ukraine suitable organizing and technological arrangements in order to overcome the deficit of horticultural production. It is, in particular, a question of deepening of zonal specialization and increasing of state protectionism or both, domestic production and scientific, first of all selection and genetic, studies aimed to the increase of the anthropoadaptive potential of the whole horticulture and in particular the anthropoadaptability of new cultivars.

Consequently, key elements of the strategy and particular details of horticulture improvement are developed by researchers of universities and academic research institutes concerning biological peculiarities of new pear cultivars (*Pyrus communis* L.) in the Ukrainian Pridnestrovya; the amino acid composition of strawberries fruits (*Fragaria ananassa* Duch.); the viral diseases of the representatives of the genus *Corylus* in the ecological conditions of the National Dendrological Park "Sofiyivka" of NAS of Ukraine and the production biotechnology of improved planting material, as well as the phylogenetic connections between representatives of the genus *Amelanchier* Medik., grown in Ukraine as an initial material for the horticultural plant breeding.

Part III is titled "Ecological Peculiarities of the Foothills of the Northern Caucasus: Cytogenetic Anomalies of the Local Human Population" and consists of four chapters. It contains the original works of the specialists of the Republic of North Ossetia–Alania. The Republic, located in the northern part of the Main Caucasian Range, is one of the most densely populated regions of the Russian Federation. The climate here is continental due to the weak influence of the seas. The vegetation period lasts from May to October, which promotes agriculture. However, zoning mountain and foothill areas creates difficulties for agriculture and the cultivation of forage grasses. Confined space contributes to the accumulation in the soil, air, and in plants of heavy metals of hazardous industries. Analysis of genetic changes in humans confirms this.

There is a need for conducting environmentally sound agriculture. Grasses and leguminous plants play a significant role in solving this problem. They have a significant impact on the preservation and restoration of soil fertility and are the most efficient source of cheap highly nourishing fodders for livestock.

In the review paper "Introduction of Clover Species (*Trifolium* L.) in the North Caucasus," it was studied that wild species of clover in contrasting environmental conditions on different heights of mountains (600, 800, 1300, 1600, and 2000 m above sea level).

The important role for environment is played by the water supply in the region. These data in detail are presented in the chapter "Sources of

Fresh and Mineral Water in North Ossetia—Alania." The current climatic and industrial conditions have increased the level of environmental pollution with heavy metals. The following chapter, "Detoxification of Soils Contaminated with Heavy Metals," describes biological methods of evaluation of heavy metal in the soil and air and proposes a method of detoxification of the soil using the clays and zeolites. In "Genetic Health of the Human Population as a Reflection of the Environment: Cytogenetic Analysis," it was studied the cytogenetic and demographic aspect of monitoring the population living in conditions of high anthropogenic pressure. Environmental pollution by heavy metals affects the genetic health of the population. A study of the correlation of mutational load in the population with birthrate dynamics in 1996–2000 and 2008–2012 have shown that the higher the frequency of spontaneous abortions and preterm births, the less likely the birth of children with congenital anomalies and vice versa.

Part IV is titled "Phenogenetic Studies of Cultivated Plants and Biological Properties of the Seeds" and consists of four chapters. This part is dedicated to one fundamental task of farming—preserving and expanding biodiversity of cultivated plants in difficult soil and climatic conditions of Western Siberia. In the Department of Botany, Biotechnology and Landscape Architecture of Tyumen State University jointly with Tyumen Strong point of N.I. Vavilov All-Russian Research Institute of Plant Industry, forming and storaging the valuable collections of cultivated plants are carried out. According to the results of the study in the Tyumen region, world collection of barley from VIR possesses valuable characters for breeding ("Ecological and Biological Study of Collection of Genus *Hordeum* L."). A new breeding material of spring wheat, possessing the wide adaptive capacities, also was created. Field germination and viability of plants during the growing season served as an indicator of ecological plasticity of hybrid of spring wheat. In this case, locally adapted cultivars and the best examples of the world collection were involved for hybridization. In the chapter, "Reaction of Collection Samples of Barley (*Hordeum* L.) and Oats (*Avena* L.) on Chloride Salinization," the authors have shown the resistance to the chloride stress on criteria of the ability of seeds to germinate and the variability of parameters of plantlets in the lab. The selection of salt-tolerant specimens of the oats and the barley are considered as valuable source material for breeding and genetic programs. The chapter "Resistance to the Impact of Biotic and Abiotic Factors of the Environment" studies the field seed germination and biological resistance of the parent cultivar plants and hybrids F_1–F_4 of the soft spring wheat in sharply changing climatic conditions and cultivar of soil types of the Western Siberian Lowland. The hybrid forms were studied within four years (2010–2013). From them were singled out samples having a wider adaptive capability according to the indexes of the field seed germination and biological resistance of the plants. The chapter "Comparative Trials of Variety Samples of Eastern Galega (*Galega orientalis* Lam.)" presents the characteristics of samples of *Galega orientalis* on morphological and economically valuable traits in the competitive test. It was found that the studied samples of *Galega orientalis* differed significantly from each other in color of flowers, leaves, seeds and other morphological characteristics. According to the results of a comprehensive evaluation of the economically useful traits, cultivar samples SEG-7, SEG-10, and SEG-12 were characterized by higher rates.

Part V is titled "Anthropogenic Pressure on Environmental and Plant Diversity" and consists of four chapters. The chapter "Plant Response to Oil Contamination in Simulated Condition" deals with response of perennial gramineous (awnless brome, red fescue) and leguminous (red clover) grasses to influence hydrocarbons at different stages of ontogenesis in laboratory and field conditions. The topic of oil pollution is addressed in the article. The observations show that treatment of seeds by hydrocarbons of oil soil pollution can result in both growth inhibition and in the stimulation of growth depending on the reactant concentration and from plant species. The chapter "Influence of Anthropogenic Pressure on Environmental Characteristics of Meadow Habitats in the Forest and Forest-Steppe Zones" deals with the use of modern methods of ecological and geobotanical studies. It was revealed that human pressure changes the basic environmental characteristics of mesic grasslands in a Forest and Forest-Steppe zones of Ukraine. The general trends of changes are decreasing of soil moisture, increasing of soil reaction, and rise of nutrient content in the soil. These patterns should be considered in organization of environmental management and monitoring of natural grasslands, for the development of optimal regimes of grazing, mowing, and recreation.

The chapter "Botanico-Geographical Zoning of the Upper Dnieper Basin on the Base of the J. Braun-Blanquet Vegetation Classification Approach" is an important theoretical direction of modern botany and, in particular, geobotany. Approaches to the allocation of the main botanico-geographical units are constantly being improved. In European countries, the widespread J. Braun-Blanquet approach for vegetation classification today is increasingly used also in zoning. In this regard the presented work on the using of syntaxonomy for the aims of zoning of the Russian part Upper Dnieper basin is very actual.

Part VI is titled "Methods of Evaluation of the Quantitative and Qualitative Characters of Selection Samples" and consists of six chapters. The Pryanishnikov All-Russian Scientific Research Institute of Agrochemistry is the scientific-methodical center of the geographical network of experiments with Russian fertilizers. The collection includes the most significant, at the level of discoveries, scientific works on the study of investigation and regulation of the substance circulation in ecosystems and agrosystems. These scientific works were done in recent years by well-known Russian agrochemists. Studying precision agriculture allowed the identification of previously unknown statistical and agrochemical regularities in the variation of within-field soil fertility ("Accounting Within-Field Variability of Soil Fertility to Optimize Differentiated Fertilizer Application"). They can serve as a theoretical basis for the development of efficient technologies of differentiated fertilizer application, taking into account the heterogeneity of the soil cover. In general, studies display this work on the level of scientific discovery. In another chapter, "Transformation of Mobile Phosphorus in the Soils of Agroecosystems During Prolonged Trials," some new regularities of transformation of phosphorus in soils under long-term interaction between fertilizer and soil are shown. These regularities permit the prediction of the content of mobile phosphorus in the soil for the long term and determine the need for agricultural crops in phosphate fertilizers. The chapter "Sustainability of Agrocenoses in the Use of Fertilizers on the Basis of Sewage Sludge" discusses the theoretical and practical aspects of rational use in biological systems domestic wastes of communal services. It is shown that municipal waste is on one hand a source of environmental pollution and on the other raw materials for the production of valuable fertilizer funds. Application of processed waste as organic mineral fertilizer assists in the closing of a significant portion of the small biological cycle, and helps to protect the environment from contamination of biological wastes.

Particular interest from a bioecological point of view attracts the work (in Part V) "Dynamics of the Floristic Diversity of Meadows as a Stability factor of Herbaceous Ecosystems," revealing in a historical perspective the nature of the interaction in the soil-plant-animal system. The role of vegetation in the formation of soil cover was noticed by Leonardo da Vinci; however, the linkages between all elements of this ecosystem have not previously been considered. This article shows that the usual, at first sight, processes of changing the floristic composition of herbaceous ecocenoses were caused by the historical interaction in the system of plant–animal, and ultimately aimed at conservation of soil as the basis for the existence of plants and animals on land part of our planet. For the first time the author revealed the role of weeds, for example, uneatable plants, as planetary protection function of soils from pasture soil erosion. He also explains that the emergence of weeds on arable land is a protective reaction of nature against the violation of the integrity of grassy ecosystems. In another chapter, "Gas Discharge Visualization of Selection Samples of *Trifolium pratense* L.," a new physical method of gas discharge visualization was developed. The plants, leaf blades of which have a high intensity of luminescence, differ with largest percentage of sugars. The GDV-bioelectrography allows in short term to produce a selection of samples of red clover by sugar content, as well as to assess the impact of X-rays on the vitality of clover plants derived from irradiated seeds. The chapter "Application *Galega orientalis* Lam. for Solving Problems of Reduction the Cost of Forage" has proposed a method of cultivation of valuable fodder crop *Galega otientalis* Lam. to improve the gustatory quality of green mass and improve the quality of harvested forage. *Galega otientalis* Lam. should be cultivated in a mixture with components of cereals and legumes. And it should take into account the timetable for cleaning cover crop, and should take into account the need for adding to the soil of certain mineral fertilizers. In “The Effect on the Incidence and the Development of Malignant Tumors” chapter, the effect of different doses of savory essential oil on the development of spontaneous leukemia was studied on mice. The drug efficiency was determined from the survival curves, animal life spans, and the incidence of leukemia. The savory essential oil in low doses added with drinking water (150 ng/mL) or with feed (2.5 μg/g) increased the average lifetime of mice by 20–35%. The low doses of essential oil from this aromatic plant seems promising as a prophylactic agents.

The articles in this volume are from the following scientific institutions:

- Bashkir State Agrarian University, Ufa, Republic of Bashkortostan, Russia;
- Belorussian State Agricultural Academy, Gorki, Republic of Belarus; Bryansk State University, Bryansk, Russia;
- Gorsky State Agrarian University, Vladikavkaz, Republic of North Ossetia (RNO–Alania), Russia;
- Institute of Biomedical Research of Vladikavkaz Scientific Center of the Russian Academy of Sciences and the Government of the Republic of North Ossetia–Alania, Vladikavkaz, RNO–Alania, Russia;
- Institute of biomedical research of Vladikavkaz Scientific Center of the Russian Academy of Science, RNO–Alania, Russia;
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- Station of Agrochemical Service “Northy Ossetia,” Vladikavkaz, RNO–Alania, Russia;
- National Dendrological Park “*Sofiyivka”* of NAS of Ukraine; Uman National University of Horticulture, Uman, Cherkasy region, Ukraine;
- National University of Life and Environmental Sciences of Ukraine;
- Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine, Kyiv, Ukraine, Storozhynets district, Chernivtsi region, Ukraine;
- Emanuel Institute of Biochemical Physics, Russian Academy of Sciences, Moscow, Russia;

- North East Agricultural Research Institute, Kirov, Russia;
- Vyatka State Agricultural Academy, Kirov, Russia;
- Pryanishnikov All-Russian Scientific Research Institute of Agrochemistry, Moscow, Russia;
- Tyumen State University, Tyumen, Russia;
- N.I. Vavilov Research Institute of Plant Industry, St. Petersburg, Russia.

—Anatoly I. Opalko, Larissa I. Weisfeld, and Gennady E. Zaikov

PART I

PLANT BREEDING UNDER ADVERSE CONDITIONS OF ACID SOILS

CHAPTER 1

BREEDING OF GRAIN CROPS IN EXTREME CLIMATIC CONDITIONS

GALINA A. BATALOVA, IRINA N. SHCHENNIKOVA, and EUGENE M. LISITSYN

CONTENTS

ABSTRACT

The zone of activity of the North-East breeding center are characterized by a complex of the adverse ecological factors caused by low natural fertility of widespread podzolic soils, a variation of temperatures and non-uniformity of distribution of precipitations. On the other hand successes of breeding of varieties of intensive type considerably lowered their resistance to stressful ecological factors. Efficiency of breeding is provided, along with studying of questions of genetics of quantitative and qualitative traits, with use of selective and stressful backgrounds; with a network of ecological test for territories of Volga-Vyatka region. It allows receiving varieties with high plasticity and stability of the genotype, providing formation of yield stable on years and territories under conditions of stressful agriculture. The combination of limiting (provocative) and favorable backgrounds, laboratory and greenhouse experiments has allowed to obtain varieties of cereals characterized by tolerance and/or resistance to soil acidity and to drought: oats Faust, Dens, Krechet, Gunter, Eclips, Sapsan, and Avatars; barley Dina, Ecolog, Lel, Novichok, Pamiaty Rodinoy, Rodnik Prikamia, and Tandem. These varieties are created with use of methods as traditional breeding (hybridization, selection) and biotechnologies. The special attention in biotechnological programs is given to a combination of high potential efficiency of varieties and ability to resist to action of abiotic and biotic stressors. Methods of cellular selection are developed for reception of an initial material of barley and oats resistant against a drought and toxicity of aluminum on acid soils.

1.1 INTRODUCTION

Instability of manufacture of an oats and barley in Volga-Vyatka economic region of the Russian Federation is related with extremeness of natural-environmental conditions of agriculture on a considerable part of territory, unstable distribution of precipitations and heat on years and territory.

Successes of breeding of varieties of intensive type in last 30 years, unfortunately, have considerably lowered their resistance to stressful ecological factors that is expressed in instability of grain productivity. The spectrum of early ripening varieties and varieties of a fodder direction cultivated for green forage was simultaneously reduced in various soil-climatic territories of Russia. It specifies in necessity of expansion of researches on breeding of cereal of various groups of ripeness and directions of use taking into account quality of grain and of dry matter. Along with it, the scientific basis of a technological complex of manufacture of stable on years high crop of biologically high-grade production, ways of increase of sowing and yield properties of seeds and qualitative seeds of covered and naked varieties of oats is of great importance.

1.2 MAIN PROBLEMS OF AGRICULTURE AT NORTHEAST OF EUROPEAN PART OF RUSSIA

The zone of activity of the North-East breeding center includes the Kirov and Nizhniy Novgorod regions, the Perm Kray and republics of Mordovia, Mary El, Chuvash, Udmurt which territories are characterized by a complex of the adverse ecological factors caused by low natural fertility of widespread podzolic soils, a variation of temperatures and non-uniformity of distribution of precipitations, both in growth season, and on region territory. The average long-term temperature of air in a zone of activity of the breeding center varies from 0.6°C in the north of the Kirov region to 4.1°C in the south of Republic of Mordovia.

1.3 TYPE OF SOILS OF VOLGA-VYATKA ECONOMIC REGION

Four soil sub bands: The podzolic, sod-podzolic, gray forest-steppe and chernozem soils pass through all extensive territory of Volga-Vyatka economic region. The river Volga divides economic region into Left-bank and Right-bank parts. Sod-podzolic soils on sandy, sandy-loam, and loamy parent material of soil which are characterized by fragile structure, swell, have acid reaction, and humus content no more than 2–3% (Table 1.1) are extended basically in forest-covered and more damp Left bank. The Right bank differs with the best soils and is strongly plowed up. Here are extended sod-podzolic, gray forest and chernozem soils which are formed on coating loess-like loams and clays, contain about 3 to 8% of humus, and capacity of humus horizon reaches 20–25 sm [1].

TABLE 1.1 Structure of a Soil Cover of Territory of Activity of the North-East Breeding Center (% of Total Area of Arable Land)

Republic, Kray, region	Soil types		
	Podzolic and sod-podzolic	Grey forest	Podzolized and leached chernozems
Republic of Mordovia	8.2	42.2	43.5
Republic of Mari El	79.6	6.3	—
Chuvash Republic	25.0	55.0	18.0
Udmurt Republic	82.0	16.7	—
Permsky Kray	75.0	2.7	0.34
Kirov region	80.0	9.0	—
Nizhny Novgorod region	50.0	32.0	18.0

Sod-podzolic soils differ with superficial arable layer frequently less than 16–17 sm; at gray forest and light gray soils capacity of humus horizon and an arable layer often coincides and fluctuates within 18–24 sm. At dark gray soils capacity of humus horizon reaches 35–45 sm; at podzolized and leached chernozems – 60–75 sm.

In easy and sandy soils the content of humus fluctuates from 0.5 to 1.0%, and nitrogen – from 0.06 to 0.08%. In sod-podzolic soils of loamy mechanical structure the content of humus makes 1.5–2.0%, and the total nitrogen 0.09–0.12%. In gray forest-steppe soils the content of humus fluctuates within 1.2–3.0%, nitrogen – from 0.08 to 0.16%, and in dark gray soil – accordingly within 3.0–8.0% and 0.16–0.44%. The content of humus in podzolized and leached chernozems reaches 5–10% in an arable layer, and nitrogen – 0.20–0.50% [2].

1.4 AGRO-CLIMATIC AND GEOGRAPHICAL FEATURES OF THE REGION

The climate of the Kirov region where the North-East Agricultural Research Institute (North-east ARI) settles down is characterized by the continentality accruing in east and southeast directions, and sharpness of seasonal transitions, with long, multi-snow, cold winter [3]. Cyclones and anticyclones bring into area the Arctic air from the north, moderate sea and continental air – from the west and the east. Along with others climate-forming factors (solar radiation, character of a spreading surface) it causes moderate-continental climate with long, both multisnow and cold winter and with moderately warm summer [4].

The area is located in the North-East of the European part of the Russian Federation between 56° and 61° of northern width, in Predural, and occupies 120.8 thousand km^2 from which 2.6 million hectares makes the arable land [5]. The area is extended from the north on the south on 570 km, from the west on the east – 440 km. The big extent of area from the north on the south causes distinctions as in solar energy inflow and a temperature mode. The annual radiating balance fluctuates from 22 kcal/sm^2 in the north to 25 kcal/sm^2 in the south, mid-annual temperature – from 0.6°C to 2.76°C accordingly. The quantity of an atmospheric precipitation decreases from the Northwest for the South-East [6]. The area is in a zone of sufficient humidifying, however loss of precipitations on months and their distribution on territory is unequal, and 75–80% drop out during the warm period of year. The amount of precipitation decreases in a direction from the north to the south. The sum of precipitations per year makes 400–500 mm in the extreme south and 550–625 mm in the Northwest and the north; during growth season, accordingly, 250–300 and 320–400 mm. The high danger to agriculture of the region is represented by the droughty periods in two decades and more, marked on the average one time in five years. On the average for the warm period it is observed 20–35 droughty days, in separate years 30–60 days happen without a rain [7].

The growth season makes 155–170 days (from April, 20–29th till September, 26th – October, 8th) that is 40–60 days exceeded the period necessary for cultivation of spring grain crops. The sum of daily average temperatures of air between transition dates through 10°C in spring and in fall makes 1550–2175°C.

Territories of Kirov region are divided into three agro-climatic latitudinal zones considerably differing under natural and climatic factors: northern, central and southern.

Northern agro-climatic zone is the coldest and damp. The sum of active temperatures makes 1700°C. The mid-annual temperature of air makes 1.5–2°C. Number of frost-free days is 192–203 [5]. The period of active growth of agricultural crops consists 105–115 days. The zone territory almost completely is in a strip of superfluous humidifying.

The central agro-climatic zone is characterized by moderately warm and damp climate. The greatest quantity of precipitations is in the central part of a zone. The sum of active temperatures changes from 1700 to 1900°C. Duration of active growth of plants – 116–120 days. The central zone can be divided into the western and east areas characterized by various moisture supplies. In the western area the amount of precipitation in period of active growth of plants is sufficient, but changes on years. East area is characterized by non-uniform drop of precipitations during growth season. Dry winds and droughts are observed.

The southern agro-climatic zone of the Kirov region is on the first place on security with heat and on the last – on security with moisture; the sum of daily average temperatures above 10°C equals 1900°C. The period of active growth of agricultural crops makes 126–135 days [8].

Soil cover of the Kirov region is motley; poor podzolic and sod-podzolic soils (83% of all areas) of various mechanical structures prevail. They differ by raised acidity, the low content of humus and low capacity of compost horizon meet in all three subbands [9]. The average content of humus – 2.17%, and soils with the content of humus less than 2.1% occupy 954.1 thousand hectare (44.8%). Security of soils of area with micronutrients is low. In many areas there is a negative balance of humus, there is an irreversible process of soils de-humification. Granulometric soil structure is basically heavy, very dense, badly air – and water-permeable. In the majority they require radical improvement: liming and regular entering of organic and mineral fertilizers [10].

Real podzolic soils occupy northern areas covering middle taiga subband and northern part of a South taiga subband. Sod-podzolic soils dominate in the central part and in the south of a zone. In a southern zone of area there are more fertile light gray forest soils (9%), besides in small amounts (1–4%) in area there are sod-podzolic gley and gleyic, sod-gley, sod-carbonate, and gray forest soils [11].

The analysis of quality of farmlands shows that the steady tendency to active degradation of the soil cover caused by absence of effective measures on preservation and reproduction of soils fertility is observed everywhere in territory of the Kirov region. By results of last cycle of agrochemical inspection acid soils occupy 72.7% (1548.1 thousand hectares) of the arable land areas; 530.4 thousand hectares or 24.9% of arable land have low content of mobile phosphorus and 511.5 thousand hectares or 24% of arable land have low content of exchange potassium that limits their efficiency. The cited data characterizes fertility of soils of the region as low, corresponding to natural fertility of sod-podzolic soils [11].

The presented data testifies to different level of natural fertility of various soils of Volga-Vyatka economic region that predetermines (along with weather conditions) a corresponding set of cultures and structure of areas under crops, specificity of cultivation of agricultural plants and ways of increase of soil fertility. As a whole a climate and soils of Volga-Vyatka region correspond to agro-biological requirements of cereals to growth conditions and are favorable enough for cultivation of oats and barley for seeds, the food and fodder purposes.

Efficiency of breeding is provided, along with studying of questions of genetics of quantitative and qualitative traits, with use of selective and stressful backgrounds; with a network of ecological test for territories of Volga-Vyatka region. It allows to receive varieties with high plasticity and stability of the genotype, providing formation of yield stable on years and territories under conditions of stressful agriculture: the growth period is short and insufficiently provided with the sum of effective temperatures; low fertility and high acidity of soils of podzolic type; drought display during the various periods of plant growth; return of colds and frosts during growth season (before middle of June and after second half of August); non-uniform distribution of precipitations.

1.5 POSSIBILITIES AND SUCCESSES OF CREATION OF ADAPTIVE VARIETIES OF AGRICULTURAL CROPS IN NORTH-EAST BREEDING CENTER

1.5.1 SOME HISTORICAL FACTS

In the end of twentieth to beginning of twenty-first century oats and barley breeding in the North-East breeding center has received a new orientation. Along with productivity, resistance against pests and precocity works are spent on creation of adaptive varieties resistant and/or tolerant to edaphic stresses providing reception of economically defensible yield of qualitative production. The great attention is given to working out of theoretical bases of breeding; studying of features of biology of flowering and photosynthetic activity of oats and barley in favorable and stressful conditions; working off of methods of hybridization, principles of selection of initial material for crossing. For creation of an initial material, along with hybridization and selection, the biotechnology method is applied – reception of regenerants on rigid aluminum selective environments at selection on acid-resistance and osmotic – on drought resistance.

Working out of laboratory express methods of screening of varieties on acid- and drought resistances, differentiations of an initial and selection material, to allocation of forms contrast on stability and an estimation of efficiency of laboratory methods in field conditions is carried out. The estimation method on the root index is used in selection allowing not only to differentiate correctly selection lines, but also to conduct selection of a perspective material with obtaining of seed progeny for further breeding work on stress resistance. Target selection of oats grain for processing, including naked forms develops; breeding of fodder oats and varieties of a universal direction of use is renewed.

Level of productivity of agricultural crops is genetically determined trait; however potential possibility of a variety to give a real crop depends from soil-environmental conditions of plants growth and level of resistance of a variety to stressful ecological factors of environment. Edaphic stress caused by ionic toxicity of aluminum and manganese, related with low pH, for example, soil acidity is count as the most important economic and ecological stresses. The share of such soils all over the world makes about 40% [12]. In structure of acid soils of the Kirov region very strongly acid (pH less than 4.0), strong acid (pH 4.1–4.5) and average acid soils (pH 4.6–5.0) consist 1012.8 thousand hectares [13].

1.5.2 SOIL ACIDITY

The major factor defining toxicity of acid sod-podzolic soils of the European part of Russia is high level of the content of mobile (exchangeable) ions of trivalent aluminum. Toxicity of Al^{3+} is the leading factor reducing efficiency of plants on 67% of all acid soils [14]. Aluminum interferes with active absorption of phosphorus, competes to calcium, and inhibits division and elongation of cells of absorbing organs. The size of root system thus decreases its ability to absorb water and nutrients decreases.

1.5.3 PHOTOSYNTHESIS

The lack of nutrients directly and indirectly influences photosynthesis. In this relation studying of influence of acidity of sod-podzolic soils on the content of chlorophyll *a* and *b*, carotenoids in leaves of the upper layer and final productivity of plants [15, 16] is of interest. Edaphic stress of acid soils made essential impact on change of the area of flag and second leaves, the total area of leaves. The flag leaf has been most subject to negative influence of soil acidity. Depression of the area of flag leaf under conditions of stress in comparison with neutral soil background has made in our studies 38.5–72.9%, of second leaf 19.4–63.9%, and the total area of leaves 18.8–63.5%. Depression of chlorophyll *a* content in the conditions of stress has made for flag leaf 17.8%, for second leaf – 41.7%; of chlorophyll *b* 36.7% and 61.3%, of carotenoids 7.7% and 33.9%; for the sum of a chlorophyll $a + b$ 22.1% and 45.9% accordingly. Content of carotenoids and ratio of chlorophyll/carotenoids in flag leaf has rendered the greatest influence on productivity of oats plants in the conditions of stress ($r = 0.77$ and $r = 0.80$ accordingly); chlorophyll *a* and chlorophyll *b* contents in flag ($r = 0.69$ and $r = 0.78$) and second ($r = 0.53$ and $r = 0.78$) leaves. Similar influence of pigment content in flag and second leaves is noted on number of grains per panicle.

1.5.4 ALUMINUM RESISTANCE

Despite the fact that selection on resistance to biotic and abiotic factors, as a rule, leads to decrease in potential productivity in non-stressful environmental conditions, creation of varieties with a combination of the given traits is obviously possible. The researches spent on the large set of oats of world collection of All Russia Institute of Plant Industry (VIR, St. Petersburg, Russia) have shown that level of aluminum resistance does not depend on a place of origin of a variety, and obtaining of resistant forms is possible among samples of any origin [17]. Breeding on drought resistance becomes complicated with absence of the sources combining high productivity and stress-resistance [17]. The analysis of a genetic variability on studied trait and search of new genetic resources for carrying over of desirable trait is represented actual.

1.5.5 RESULTS BREEDING OF OATS

The combination of limiting (provocative) and favorable backgrounds, laboratory and greenhouse experiments has allowed to obtain in 1992 the selection lines of oats characterized by tolerance and/or resistance to soil acidity and to drought. High-yielding (8.5–9.0 t/ha) varieties Faust (tolerant to soil acidity and to drought) and Dens (early-maturing and drought-resistant) have been transferred to State Test in 1999 and in 2002 are included in the State Register. After that the plastic variety Krechet combining productivity up to 9.1 t/ha with resistance to toxicity of acid soils caused by aluminum ions has been created and admitted to use in agricultural industry since 2005. Varieties Gunter and Eclips are characterized with high grain (up to 11.2 t/ha) and productivity fodder are suitable for cultivation on grain-hay technologies and are included in the State Register in 2007 and 2012, accordingly. In 2009, variety Butsefal of a universal direction of use is transferred to the State Test: it is high-yielding on grain (up to 8.7 t/ha) and on dry matter (up to 10.6 t/ha); adaptive, capable to form high stable grain yields at various ecological-geographical points; with high nature of the grain; poorly defeat with loose smut; resistant against damage by the Swedish fly. In 2012 works are finished on breeding of adaptive to biotic and abiotic ecological factors covered varieties of oats Sapsan and Avatars of a universal direction of use (on grain and green mass).

1.5.6 INHERITANCE OF VALUABLE TRAITS

Despite a variety of methods of breeding, along with selection and hybridization we use mutagenesis, post-genome technologies, genetic transformation; a basis of success is knowledge and understanding of inheritance and preservation in progeny of the traits defining productivity of a variety.

Insufficient knowledge of genetics of quantitative and qualitative traits in selection leads to necessity of a considerable quantity of crossings. At crossing of the individuals differing on quantitative traits, dominance of trait of one of parents is not always observed, and in second generation of hybrids there is not accurate segregation on a small number of phenotypically different classes. It complicates carrying out of screening after crossing as genetic variability intertwines with the ecological in progeny. The success of selection depends both on effect of action of genes, and on character and degree of inheritance of trait of interest [18].

1.5.7 TRANSGRESSIONS

The transgression phenomenon is considered important in the selection when at crossing of the organisms different from each other on quantitative expression of a certain trait in hybrid progenies there are stable forms with much stronger or weaker expression of a corresponding trait than it was in initial parental forms. It occurs when one or both parental forms do not possess extreme degree of expression of a trait, which the given genetic system can give.

In connection with the progress in breeding of grain crops the set of highly productive forms, which can be used as components of crossing for reception of transgressions on the basis of high grain efficiency or on separate components of efficiency, has considerably extended. It also complicates somewhat the problem of a choice of the best component. For the most economic and exact selection of components of crossing application of quantitative methods of an estimation of traits of an initial material is necessary [19].

1.5.8 THE USE OF BIOTECHNOLOGY IN BREEDING

For increase of efficiency of selection of cereal crops introduction of the new biotechnological methods allowing to design the genotypes on the basis of cellular engineering is necessary. One of such methods in creation of new forms of plants is reception of somaclonal variants in callus culture. Somaclonal changes arise in process of cultivation of isolated cells and tissues as a result of mutations, a various expression of genes, and somatic crossing-over [20, 21].

The variability arising in vitro is not always adaptive: separate traits can change as towards increase, and fall of values in comparison with an initial variety [22]. Somaclonal variability gets adaptive advantages, if selection is possible to carrying out in in vitro system. For selection of resistant forms at cellular level selective media are used which simulating natural stressful conditions provide an expression of a trait of resistance and give the chance to select the necessary variants.

1.5.9 SUCCESSES IN BREEDING OAT AND BARLEY

Complex researches on studying of an initial material on breeding valuable traits, obtaining of sources and donors, an estimation of combinational and adaptable possibilities of a material involved in selection provide high efficiency of researches in the field of barley and oats breeding in the North-East Agricultural research Institute (Kirov, Russia). During activity of the breeding center it is created more than 100 varieties of different agricultural crops which most part was successfully cultivated, in due time, on fields of Russia and the countries of the former Soviet Union. Now 188 varieties of spring barley are included in the State Register of protected selection achievements of the Russian Federations admitted in manufacture and 109 varieties of oats; some of them are bred in North-East Agricultural research Institute: 8 barley varieties (Dzhin, Dina, Ecolog, Lel, Novichok, Pamiaty Rodinoy, Rodnik Prikamia, and Tandem) and 10 oats varieties (covered oats Argamak, Dens, Eclips, Fakir, Faust, Gunter, Krechet, and Teremok, naked oats – Persheron and Vyatsky).

These varieties are created with use of methods as traditional breeding (hybridization, selection) and biotechnologies. The special attention in biotechnological programs is given to a combination of high potential efficiency of varieties and ability to resist to action of abiotic and biotic stressors. Methods of cellular selection are developed for reception of an initial material of barley and oats resistant against a drought and toxicity of aluminum on acid soils. Methods are improved of creation of rigid selective nutrient mediums with pH 3.8 and concentration of ions of aluminum up to 40 mg/L. The structure of organogenic media is modified that has allowed to achieve reception in high quantity of plant-regenerants of barley and oats resistant against aluminum.

The first aluminum-tolerant barley variety Novichok is created with use of selective medium and earlier received variety – dihaploid Duet. On acid soils with pH 4.0 and the content of aluminum up to 7.9 mg/100 g of soils variety Novichok exceeds the standard on 10.9% at productivity of 5.6 t/ha. The variety has field resistance to black and covered smut, is characterized with high tillering capacity. Dihaploid variety Tandem is received with use of wild bulbous barley as haplo-producer. Varieties Ecolog, Pamiaty Rodinoy, and Rodnik Prikamia are created which have high productivity with a complex of economic valuable traits.

KEYWORDS

- **additive effects**
- **alleles**
- **correlation**
- **dominance**
- **hybrids**
- **oats**

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CHAPTER 2

GENETICS OF QUANTITATIVE TRAITS OF PRODUCTIVITY AND QUALITIES OF GRAIN OF OAT *AVENA SATIVA* L.

GALINA A. BATALOVA and EUGENE M. LISITSYN

CONTENTS

ABSTRACT

For hybrids from crossing of oats covered varieties Argamak, E-1643, Ulov (Russia), Freja, Petra (Sweden) with naked oat variety Torch (Canada) it is established that additive effects prevailed in F_1 in the genetic control of traits "plant height," "number of spikelets per panicle," "number of grains per panicle," "grain mass per panicle" and "1000 grains mass"; effects of overdominance prevailed in F_2, except of a trait "plant height". Additive effects prevailed in the control of all traits in F_3 that testifies to possibility of effective screening of lines with breeding valuable properties of genotypes. Covered hybrids Freja x Ulov, E-1643 x Ulov, E-1643 x Argamak, Ulov x Argamak, and naked hybrids Freja x Torch, Torch x Freja, Torch x Argamak had the best combination of some breeding valuable traits. The greatest number of transgressive forms has been segregated in combinations with participation of varieties E-1643, Ulov, Petra, and Freja. Significantly high mass of grain per panicle (productivity) in comparison with parental naked variety Torch (1.26–0.91 g) was observed in the first – the third generations of naked hybrids Freja x Torch (2.64–1.56 g), Torch x Freja (1.65–1.44), and Torch x Argamak (2.20–1.35).

2.1 INTRODUCTION

Considerable part of breeding valuable traits of plants is quantitative. Their hereditary distinctions are caused by interaction of several pairs the polymeric genes, thus each gene makes essential impact on development of the given trait or quantitative traits are more strongly dependent on external factors, than qualitative traits. Selection on quantitative traits in early generations of hybrid populations is complicated because genetic variability in progeny is combined with ecological; in F_2, for example, there is no accurate segregation on small number of phenotypic different classes. The success of selection depends both from effect of action of genes and from character and degree of inheritance of those trait on which selection was led [1].

There are some approaches to the description of inheritance of quantitative traits. The *phenomenological* approach unites set of methods and techniques of the description of inheritance, which do not contain enough accurate data on the mechanism of inheritance of a trait. Methods of mathematical statistics allow to estimate possibilities of selection and to predict its results not less correctly than it can be made by means of indexes of heritability and genetic correlations [2].

Principles of Mendel's genetics are use widely enough at the description of inheritance of quantitative traits [3, 4]. Thus the clear boundary between quantitative and qualitative traits does not exist they differ among themselves both on character of a variation, and on phonotypic variability within a specie [5–7]. Simple quantitative signs concern: "duration of the period germination – leaf-tube formation," "plant height," "length of an ear," "number of spikelets per ear," "1000 grains mass," etc., variability at which does not exceed 10% [8, 9]. The *genetic analysis* assumes reception of such knowledge of trait genetics, as number of genes and their alleles, localization of these genes in linkage groups, survival rate of genotypes, a way of phenotypic realizations of a genotype, interaction of genes, and environmental modification of a trait.

Genetic-and-biometric approach is widespread enough at studying of inheritance of quantitative traits too; it is related with the analysis of components of expansion of phenotypic and genotypic variance of a trait and their using in selection. Indexes of heritability [10] characterize a share of genetically caused variation within the total variation of a trait. It is accepted to distinguish heritability in broad and narrow sense of a word, understanding as last a share of additive variance in total phenotypic heritability. Heritability indexes in the broad sense of the word characterize independence of phenotypic display of a trait from a variation of environmental conditions. Heritability indexes in narrow sense characterize genetic heterogeneity of populations. Estimation of coefficient of heritability in the narrow sense of the word, characterizing the additive effects of genes transferred from parents to progenies is of great value [11]. Despite existing lacks, heritability coefficients are the simplest parameters allowing to judge roughly reliability of selection of the best genotypes by phenotypes in a certain situation.

Before revealing the phenomenon of redetermination of the genetic organization of a quantitative trait the conception of polygene inheritance by Kenneth Mather predominated in genetics of quantitative traits, created on the basis of Mendel's model [12]. The given concept assumed that environmental variability of a trait is based on change of activity of genes in a stable polygene system of a trait, and any fluctuations of environmental conditions generate ecological variability, changing only the activity of loci in the polygene system, constant by its gene set [13].

In 1984 a new model of the organization of a complex quantitative trait of plants [14] is published. Unlike methods of "*the genetic analysis*," the model of the ecological-genetic control studies not just the traits but six genetic-physiological systems by means of which the breeders can improve species on complex quantitative properties of productivity [13, 15]. The phenomenon of redetermination of the genetic formula of quantitative trait radically changes former representations about rigid unequivocal determination of complex traits. Two phenomena leading to loss of stability on a way "products of genes – a quantitative trait" are established: change in the spectrum of the loci determining the level and genetic variability of a quantitative trait at change of the limiting factor and change in the spectrum of modules [16, 17]. The module is an elementary unit of the description of the organization of a quantitative trait consists of three interrelated traits: one resultant and two componential. They are arranged in "pyramids" of modules. At change of external limits componential modules change their contributions into a final resultant trait [15]. At increase of level of a trait in hierarchical system of modules degree of its variability increases too.

Revealing and the account of the basic laws of display of correlation dependences between productivity traits in various ecological and cenotic conditions allows to raise efficiency of breeding of new varieties [13, 15, 18]. In process of reduction of values of ecological intravarietal correlation among modules degree of influence of abiotic factors on display of these correlations increases. Softening of pressure of limiting factors strengthens considered correlations [19].

The new model explains why and how parameters of genetic inventory will move from one environment by another [13], gives the chance to identify a genotype of a single organism on its phenotype without test of its progeny. However, to studying of genetic features of self-pollinated lines a method of diallel crossings [20–22] is applied more often. The diallel analysis allows to check up additive-dominant model – to reveal presence of non-allelic interactions and to estimate components of a genetic dispersion; gives the exact information for given exact dynamics of environmental limiting factors. Complexity of an establishment of laws of inheritance of quantitative trait consists that separate genes can possess different degree of dominance up to overdominance. Actions of separate polygenes can be not equal each other, and sum action of several genes can be not only simple additive but also become complicated with various forms of intergene interaction. In one cases some genes weaken action of others, and in others, on the contrary, strengthen it. All of these are reflected in segregation in F_2 generation [23].

Additive genetic effects are most important in plant breeding. Not additive genetic effects cannot be used in selection directly as a lot of time is required to achievement of full homozygozity of forms. Thus it is important to define presence of positively operating genes (increasing a trait) and to spend selection depending on dominant or recessive type of their inheritance [24]. In a number of works with oats the contribution of additive genetic variance into the total one is shown. In one cases prevalence of an additive part over not additive is shown for traits "grain mass per panicle," "number of grains in a panicle," "number of panicles per 1 m^2," "panicle lengths," "number of spikelets per panicle," "number of branches per whorl," "number of whorls and branches in a panicle" [25], in others cases – for traits "1000 grains mass," "panicle length," "number of spikelets in panicle" and overdominance for trait "grain mass per plant" [26].

There are indications on presence of non-allelic interactions in inheritance of such traits as "plant weight," "diameter of a stem," "1000 grains mass," "number of grains per panicle," "grain mass per panicle," "yield per 1 m^2" [27]. It is shown strong and constant non-allelic interaction for a trait "grain mass per plant," but for other traits (such as "length of a culm," "number of spikelets per plant," and "plant height") non-allelic interaction had very small value [28].

It is noticed that epistatic variance is more important component of genetic variance of yield of oat near-homozygous lines then additive variance [29]. At prevailing epistatic action of genes relation between display of trait at parents and progeny in late generations is weak or is absent. Populations F_2 and F_3 cannot contain enough number of stable epistatic forms to determined advantage of homozygous progeny in the subsequent generations. There is an opinion that screening of hybrid populations on productivity and elements of yield structure in early generations is impractical as effects of dominance prevail in the genetic control of these traits [30, 31].

Development and expressiveness of a quantitative trait appreciably depend on action of environmental factors, which can modify effect of polygenes. The quantitative trait is formed under interaction of various genetic systems and fluctuating environmental factors. As a result at identical value of a final trait componential traits have the diversified values as for the same variety in different conditions of growth and for different varieties in the same growth conditions [32, 33]. Thus, Diallel analysis gives the exact information only for given exact dynamics of limiting environmental factors; in other environment these characteristics can become others.

This character of display of quantitative trait complicates carrying out of selection after crossing as genetic variability will intertwine with the ecological variability in progeny. The success of selection depends both on effect of action of genes and from character and degree of inheritance of those trait on which selection is led [34].

At creation of valuable genotypes of oats in the conditions of Volga-Vyatka region of Russia the most effective was selection by traits "number of grains per panicle," "grain mass per panicle" and more rare by trait "1000 grains mass". Oats variety Kirovsky (Russia) and Ryhti (Finland) contain mainly dominant alleles for "grain mass per panicle," "grain mass per plant," and "1000 grains mass" but recessive alleles for grain number. Trait "grain mass per plant" in variety Cravache (France) is strongly influenced with recessive alleles but traits "number of grain in panicle," "1000 grains mass," "grain mass per panicle," and "length of panicle" – with dominant alleles. Variety Astor (the Netherlands) has approximately identical ratio of dominant and recessive alleles for the majority of traits [31].

The aim of study is to establish character of inheritance of the basic yield-forming traits and indexes of grain quality in spring oats (*Avena sativa* L.).

2.2 MATERIAL AND METHODOLOGY

The territory of the Kirov region is located in the northeast of the European part of the Russian Federation between 560 and 610 northern widths, in Predural, and occupies about 120.8 thousand km^2. A region climate is moderate-continental with long, multisnow cold winter and moderately warm summer. The growth period makes 155–170 days (from April, 20–29th till September, 26th October, 8th) that exceeds the period necessary for cultivation of spring grain crops for 40–60 days. The sum of active temperatures of air for a growth season makes 1550–2175°C. A soil cover is mosaic with 72% of poor sod-podzolic loamy soils; about 15% make sandy and sandy-loam soils of various mechanical structure. The average agrochemical parameters of soils make: humus 2–3%, pH_{KCl} = 5.0, the content of mobile phosphorus – 119 mg/kg, exchangeable potassium – 120 mg/kg. As a whole a climate and soils are favorable enough for oats cultivation for the seed-growing and food purposes.

Crossings are spent in the North-East Agricultural Institute (Kirov, Russia) on full diallel scheme with use of five covered varieties of oats (*Avena sativa* L.) – Argamak, Ulov, E-1643 (Russia), Petra, Freja (Sweden), and one variety of naked oats (*Avena nuda* L.) – Torch (Canada) (Table 2.1).

At first set of experiments F_1 hybrids and their parental forms were sowed in the field conditions in triple replications by rows in plots of 1 m width. Width of a row-spacing was 15 sm, distance between seeds in rows was 5 sm. Sowing of hybrids was spent under scheme $P_1F_1P_2$.

At second set of experiments parental forms as well as F_2 and F_3 hybrids were sowed on 1 м^2 and 2 м^2 plots in triple replication.

At sowing of F_2 and F_3 progenies grain of direct and reciprocal hybrids from crossing with naked variety Torch was divided on naked and covered and was sowed separately (covered and naked forms).

TABLE 2.1 The Scheme of Crossings

Maternal genotype	Paternal genotype					
	E-1643	**Petra**	**Argamak**	**Ulov**	**Freja**	**Torch**
E-1643		+	+	+	+	+
Petra	+		+	+	+	+
Argamak	+	+		+	+	+
Ulov	+	+	+		+	+
Freja	+	+	+	+		+
Torch	+	+	+	+	+	