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The influence of edaphic and hydrothermal factors on the properties of maternal plants, seeds and seedlings properties of spring wheat and barley cultivars

Wpływ czynników edaficznych i hydrotermalnych na cechy rośliny macierzystej, nasion i kiełków odmian pszenicy jarej i jęczmienia

Summary. We studied the possibility of seed improvement by means of the influence of different ecological factors on parent plants of *Triticum aestivum* L. and *Hordeum vulgare* L. It was established, that the dynamics of development of plants from seed obtained in different ecological conditions was influenced by hydrothermal, soil and light factors, mineral root and spray feeds of maternal plants. Differences in seed chemical structure were not marked, but different dynamics of the offspring plant development was demonstrated. An attempt was made to understand the mechanism of parent phenotype influence on posterity phenotype. It was established that organic compounds, which could facilitate transporting mineral nutrition elements into parent plants, could increase the seeds quality. Having carried out the research, we came to the conclusion that the seed quality could be improved not only by cereal breeding, but also by a special choice of cultivar specific ecological niche in which qualitative seeds could be received. In this connection, the study of "plant-soil" system functioning and the development of methods of biological correction of this system functioning and its environment factors stability increase is an important direction of recultivation of human changed territories. Certainly, such a technology of cereal seed growing is highly adaptive.

Key words: biological correction, edaphic factors, *Hordeum vulgare,* hydrothermal factor, Maternal effects, *Triticum aestivum*

INTRODUCTION

Yield per time unit and land unit has increased markedly during the last 30 years as a result of intensified crop management involving improved germ-plasm, greater inputs of fertilizers, production of two or more crops per year on the same piece of land, and irrigation [Cassman 1999; Czembor 2000; Mer et al. 2000]. For an effective settlement of problems, we must use only those approaches which take into account the laws of development and functioning of ecosystems. The main problem of recultivation is ecosystem functioning restoration.

Human influence (mechanical, chemical, thermal, etc.) on agrarian ecosystems of the Northwest Europe first effected the functioning of a "plant-soil" system and, as a consequence, all the ecosystem. This influence inevitably results in the loss of earlier trophic connections. There are the following infringements: a) phytocoenotic productivity, b) zoocoenotic richness in species (including soil biota), c) quantity and quality of organic material acting in soil, d) acidic, hydrothermal conditions.

The modern strategy of development of agriculture moves from technogenic priorities to adaptive ones ensive system of plant growing [Goodman 2000]. In this connection, the study of "plant-soil" system functioning and the development of biological correction methods for functioning and increase of stability of this system in reaction to the adverse factors of environment [Popov and Chertov 1993, 1997, 1998] is an important direction of modern investigations.

Transition to adaptive technologies demands new research of species- and cultivar-specific reactions of plants to conditions of the environment [Slafer and Rawson 1994; Calderini and Slafer 1999; Czembor 2000]. Moreover, variations in seed and adult traits caused by environmental maternal effects can have important consequences for the ecology of an individual plant [Roach and Wulff 1987; Egli 1998].

Taking these premises as a basis, we studied the possibility of seed improvement by means of different ecological factors, including the biological correction method. Having completed this research, we came to the conclusion that the seeds quality can be improved not only by cereal breeding, but also by a special choice of a cultivar specifically ecological niche, in which high-quality seeds can be obtained.

MATERIAL AND METHODS

Plant materials and experimental fields. Seven cultivars of summer wheat *Triticum aestivum* L.: Saratovskaya 29, Saratovskaya 55, Gnitsa and Moscowskaya 35 (1994–1996), Leningradka (1994–1996, 1998–1999), Krepysh, Irgina (1998–1999) were investigated. Five spring barley *Hordeum vulgare* L.: Zazerskij-85, Dvoran (1997––1998), Krinichnyj, Suzdalets, El'f (1998–1999) were used. Sowings were made from the calculation by 500 germinating seeds into 1 m^2.

The experiments were conducted in 2 fields: 1. podzol loamy soil in the Nothwest of Russia (1994–1999), 2. black earth loamy soil in the Central part of Russia (1994–1995).

Treatments and meteorological data. Fertilizers for top-dressing consisted of 16% N, 16% P and 16% K. Fertilizers were applied as control (150 kg $NPK{\cdot}ha^{-1}$) during the period of 1994–1999, 1 dose (250 kg $NPK{\cdot}ha^{-1}$) and 2 dose (500 kg $NPK{\cdot}ha^{-1}$) during the period of 1998–1999 before sowing.

The plant growth biological correction [1997–1998) was provided by organic-mineral fertilizer containing humic substances during the fist double ridge appearance phase (DR) by means of spray.

Daily rainfall (in mm) and air temperature (in ºC) were recorded at the meteorological station, located near the experimental field. Then the hydrothermal factor (HTF) was calculated for each vegetation. The calculation of the HTF is the following:

$$HTF = \frac{10 \times \Sigma}{\Sigma t}$$

where:

Σr – the sum of daily rainfall (in mm) for a vegetation;

Σt – the sum of average day temperature (in ºC), more then 10ºC, for a vegetation.

Seed weight and germination properties. Counting and weighing 100 grains on 5 replicates per plot estimated the weight of 1000 grains. The germination properties were conducted by the laboratory method. From the average sample (part of the united test, equal amount 5 point tests) a test of 50 g mass was selected, carefully mixed and moldered on the sectional board even stratum in the manner of the square. For the analysis we took 500 grains. Each test was placed in the Petri dish, bottom and top which were covered the filter paper. The cup was flooded with water of corresponding temperature. Cups were installed in thermal box with the temperature 3±1ºC, 8±1ºC, 19±1ºC, 29±1ºC without the access of light. For 4 hours the water merged and left for 16–18 hours. Then, for the maintenance of moisture, filter paper periodically moistened by water of corresponding temperature. Each day after the beginning of soaking the amount seeds, with appeared outward rootlets was counted. The experiment lasted 25 days. Sowing seed qualities were determined: energy, velocity, simultaneously germinations and germinating capacity.

Parental plant and seed biochemical analyses. We used seeds of two kinds of barley 'Zazerskij-85' and 'Dvoran') and some parts (lives and straw) of parental plants (barley 'Dvoran'). The plants were grown in production sowings. Seeds and parental plants were dried and weakly crushed. The main biochemical characteristics of seeds and parental plants are listed in tables 3 and 4, accordingly.

In plant samples we were determined a lot of characteristics: the moisture by weight method; the ashes by weight method too (after calcinations of plant samples under 800°C); the total nitrogen (N) – by Duma's method; phosphorus (P_2O_5) by colorimetric method with ammonium molybdate; potassium (K_2O) by emission spectrometry method on flame photometer; crude protein by calculation (the content of the total nitrogen was multiplied by the coefficient – 6.25); crude fat (fats, wax, pitch) by extraction with alcohol-benzol mixture (quantity of the fat was obtained by weight method); hemicelluloses, both crude cellular tissue and cellulose by Beartran's method after hydrolysis with 2% solution of HCl and 80% H_2SO_4, accordingly; water soluble carbohydrates by Beartran's method too; carbon of water soluble organic substances by dichromate method; lignin by weight method (after hydrolysis of plant samples with 80% H_2SO_4).

STATISTICAL ANALYSIS

Statistical tests were performed using the standard statistical methods Statistica-5.0 for Windows. The analyses of variance were carried by a two-way Anova. Graphs were built by least square method.

RESULTS

Influence of hydrothermal conditions on cereal plants development. At the ontogenetic level the environmental factors (temperature, humidity, fertilizers, soil, region) make an unequal contribution to quantitative parameters of efficiency. Five cultivars of summer wheat *Triticum aestivum* L.: Saratovskaya 29, Saratovskaya 55, Leningradka, Gnitsa and Moscowskaya 35 were investigated in 1994–1996. The influence of fertilizers (introduced in the soil before the sowing) decreased by the end of vegetation (from 23.8% up to 6.4%). Corn seed pouring depends more on hydrothermal conditions (27.5%) than on feed, soil and light intensity (fig. 1). Table 1 confirms this conclusion. Two cultivars of summer wheat were sown at the optimum contents of fertilizers in the central part and in the Northwest of Russia.

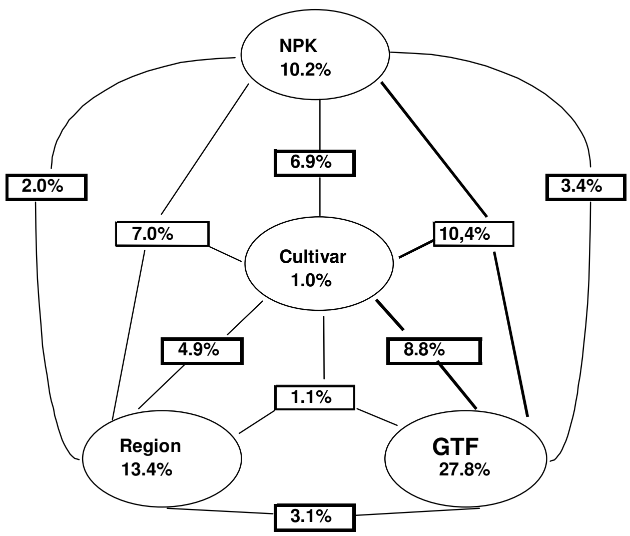

Fig. 1. Influence of hydrothermal, regional, genotypical factors and NPK on average weights of one corn seed for summer wheat. The note: oval frameworks: average main effects; the allocated rectangular frameworks: average double interactions; rectangular frameworks: threefold interactions (name of the author: Lykova)

Rys. 1. Wpływ czynników hydrotermalnych, regionalnych i genotypowych oraz NPK na średnią masę jednego nasienia pszenicy jarej. Uwaga: owalne ramy: średnie główne efekty; prostokątne ramy: średnie podwójne interakcje, prostokątne ramy: potrójne interakcje (autor: Łykowa)

Saratovskaya 29 cultivar is extensive and steady to drought. Leningradka cultivar is steady to over-moisturising. The cultivar, which was steady to drought had a higher weight of 1000 grains in very dry summer both in the central part and in the Northwest of Russia. And, on the contrary, the cultivar steady to over-moisturising gave the best result in damp summer in both regions.

Table 1. Weight of 1000 grains (m) of wheats Saratovskaya 29 and Leningradka depending on hydrothermal factor (HTF) and region
Tabela 1. Masa 1000 ziaren pszenicy Saratowskaja 29 i Leningradka w zależności od czynnika hydrotermalnego (HTF) oraz rejonu uprawy

Cultivar – Odmiana	HTF	Region	m (g)
Saratovskaya 29	0.6 ± 0.07	northwest	35.6 ± 0.92
		central	37.9 ± 1.38
	1.5 ± 0.36	northwest	26.5 ± 0.98
		central	16.6 ± 0.65
Leningradka	0.6 ± 0.07	northwest	32.0 ± 1.37
		central	29.7 ± 1.20
	1.5 ± 0.36	northwest	30.1 ± 0.95
		central	24.7 ± 0.17

Influence of edaphic conditions on seedlings and plant development of posterity. The changes in organic mineral nutrition of parent plants can be used as a factor improving seed potential ability to germination and some dynamic and structural attributes of plants of hereditary generation (fig. 2). Sufficient mineral feed was the condition of good seeds formation both for summer wheat and for summer barley (p = 0.025) (1998–1999). Barley cultivars were very sensitive to the increased doses of nitrogen fertilization, in comparison with wheats (tab. 2).

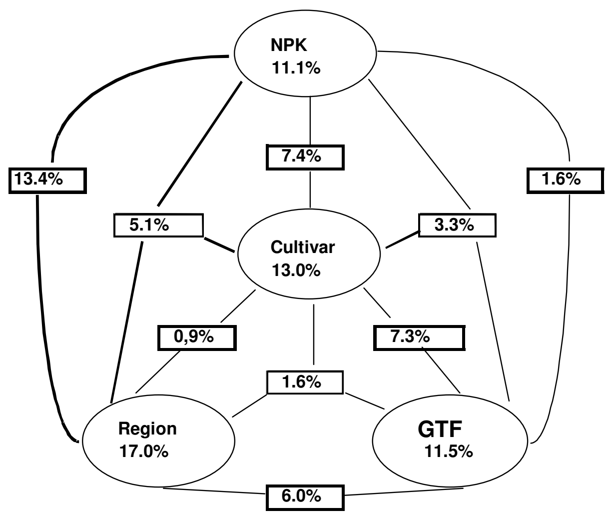

Fig. 2. Influence of preceding hydrothermal, regional, genotypical factors and NPK on average weights of one plant during spikelet phase in field conditions for summer wheat. The note: oval frameworks: average main effects; the allocated rectangular frameworks: average double interactions; rectangular frameworks: threefold interactions (name of the author: Lykova)
Rys. 2. Wpływ czynników hydrotermalnych, regionalnych, genotypowych oraz NPK na średnią masę jednej rośliny w fazie kłoszenia w warunkach polowych dla pszenicy letniej. Uwaga: owalne ramy: średnie główne efekty; prostokątne ramy: średnie podwójne interakcje, prostokątne ramy: potrójne interakcje (autor: Łykowa)

Table 2. Influence of a mineral feed (NPK) of parent plants on laboratory germination (%) of offspring seeds (19±1ºC)
Tabela 2. Wpływ żywienia mineralnego (NPK) roślin rodzicielskich na laboratoryjne kiełkowanie (%) nasion potomnych (19±1°C)

Cultivar – Odmiana	NPK ($kg \cdot ha^{-1}$)		
	150	250	500
	summer wheat		
Leningradka	76.0±4.2	83.1 ± 1.4	81.6 ± 1.4
Krepysh	62.5±3.4	80.3 ± 2.3	56.9 ± 0.9
Irgina	86.0±1.6	93.5 ± 0.4	90.4 ± 0.6
	summer barley		
Krinichnyj	92.9 ± 0.6	71.0 ± 5.6	40.3 ± 4.2
Suzdalets	89.5 ± 1.3	71.8 ± 4.8	50.0 ± 5.1
El'f	95.8 ± 0.2	72.2 ± 4.8	41.4 ± 3.3

Soil fertility significantly influenced the dynamic characteristics of seedlings in hereditary generation for wheat and barley cultivars. Trying to raise the seed formation process control, we applied the biological correction method. And it gave the expected result (see fig. 3).

Improvement of seeds quality of hereditary generation by parent plant biological correction method. Foliar nutrition of barley plants of the two investigated cultivars by organic mineral fertilizer on both biochemical composition (tab. 3) and DR phase changed potential seeds generation, formed on these plants (fig. 3).

Table 3. Chemical composition of barley (%) an absolutely dry matter
Tabela 3. Skład chemiczny jęczmienia, % absolutnie suchej masy

Parameter	Zazerskij-85	Dvoran	P
Moisture	9.90 ± 0.067	10.55 ± 0.288	0.054
Ashes	2.49 ± 0.073	2.72 ± 0.096	0.081
Total nitrogen (N)	1.86 ± 0.051	2.35 ± 0.050	0.000
Phosphorus (P_2O_5)	0.40 ± 0.015	0.43 ± 0.011	0.129
Potassium (K_2O)	0.47 ± 0.029	0.47 ± 0.025	0.865
Crude protein*	11.61 ± 0.239	14.71 ± 0.143	0.000
Crude fat (fats. wax. pitch)	1.55 ± 0.032	1.55 ± 0.069	0.983
Crude cellular tissue	4.80 ± 0.081	5.06 ± 0.080	0.045
Soluble carbohydrates	4.70 ± 0.083	5.39 ± 0.100	0.000

The note. *settlement size

The response of plants to organic mineral fertilizer containing humic substances ensured seed formation with higher germination at low temperatures (3°C and 8°C) (fig. 3) and better germination energy at temperatures from 3°C to 19°C. So, for example, germination increased 1.5 to 1.6 times with Zazerskij-85 cultivar, and 1.4 to 1.3 times with Dvoran cultivar, at temperatures 3°C and 8°C, respectively. The germination energy increased 2.5 times with Zazerskij-85 cultivar at temperature 8°C, and 5.8 times with Dvoran cultivar at temperature 3°C .

The biochemical parameters of the content of protein, carbohydrates, fat, N, P, K in a grain in the experiment remained unchanged compared to the test (non-influenced) plant seeds (tab. 3).

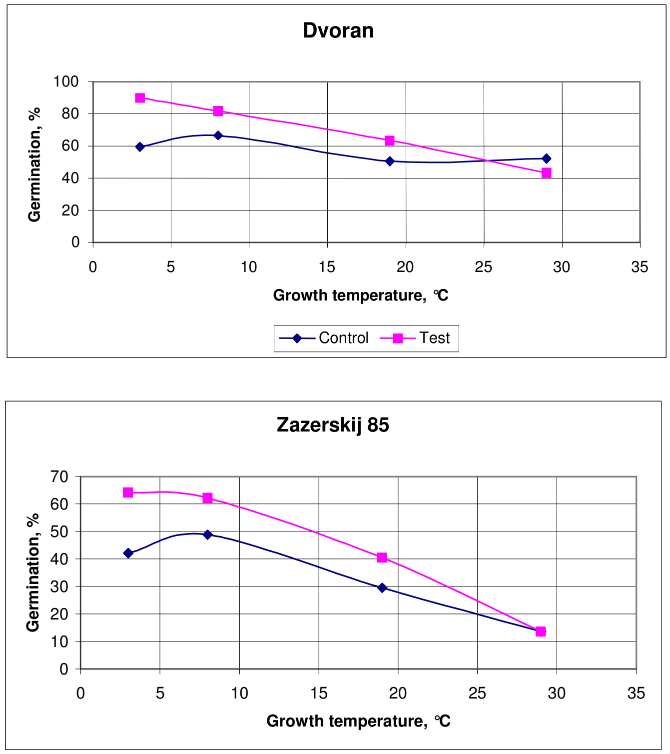

Fig. 3. Influence of a) preliminary processing of seed plants by a fertilizer solution (control, experiment) and b) growth temperature (^oC), on laboratory seeds germination of two barley's cultivars (name of the author: Lykova)

Rys. 3. Wpływ a) wstępnej obróbki nasion poprzez roztwór nawozów (kontrola, doświadczenie) oraz b) temperatury wzrostu (^oC) na kiełkowanie nasion dwóch odmian jęczmienia w labolatorium (autor: Łykowa)

The mechanism of maternal phenotype influence on the offspring phenotype in our experiment is not clear yet. Key positions for the description of this phenomenon, however, were planned. The influence of the environment or parent genotype can be transferred to posterity through a structure or physiologically. Humic substance corrects osmomolar pressure, outflow photosynthates hence amplifies, and thus the intensity of photosynthesis raises. As a consequence, the processed parent plants had increased contents of protein nitrogen (in proteins) (tab. 4). Let us remind that without correction methods the application a rational nitrogen nutrition of parent plants also improved seed potential abilities.

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Table 4. Chemical composition of barley parental plants (% on absolute dry matter)
Tabela 4. Skład chemiczny rodzicielskich roślin jęczmienia (% absolutnie suchej masy)

Samples	Ash	Water soluble organic substances		Hemicelluloses	Cellulose	Lignin	Crude proteins
		C	Sugars				
Lives (control)	12.1	6.8	3.7	22.3	18.0	21.8	19.7
Lives (experiment)	11.3	7.3	4.0	18.6	15.6	25.2	22.8
Straw (control)	8.6	2.8	2.5	23.4	23.1	27.4	12.2
Straw (experiment)	8.5	3.8	2.8	20.4	20.9	33.9	12.7

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DISCUSSION

Hydrothermal conditions influence the osmolar mechanism of nutrient's transport in plant-soil trophic system. The movement of nutrients in plant-soil system is realized by the osmolar mechanism (fig. 4). The value of gradients depends on photosynthesis activities and soil fertilization. The hydrothermal conditions influenced the ontogeny dynamics and productivity of parent plants [Halse and Weir 1970; Ford et al. 1981; Yao et al. 2000] and did not influence the seedling quantity of hereditary germination, which was proved correct by other researchers [Roach and Wulf 1987; Egli 1998].

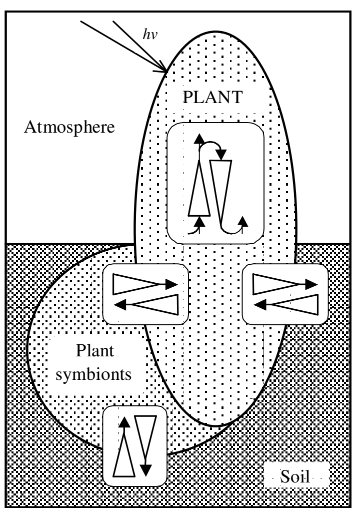

Fig. 4. Osmolar mechanism of nutrient's transport into plant-soil trophic system (name of the author: Popov)
Rys. 4. Mechanizm osmolamy transportu składnika odżywczego do troficznego systemu roślina-gleba (autor: Popov)

Influence of feed conditions on the development of cereal plants. In fig. 5 components of plant production process are given. One of production process major factors is photosynthesis. The ways of optimization of photosynthesis are investigated well enough [Williams 1927; Waksman 1937; Flaig et al. 1975]. The factors limiting it are mainly light mode, CO_2 concentration, photosynthates consumption. The optimization of soil organic mineral feed is another compulsory condition of higher efficiency achievement, as the sizes of osmomolar gradients in both directions (shoot – root and root – shoot) should be commensurable for osmomolar mechanism normal functioning of solution circulation in the whole plant. The third group of the factors concerns water supply optimization. Soil moisture stock and transport system sensitivity to temperature and atmospheric pressure fluctuations act as limiting factors.

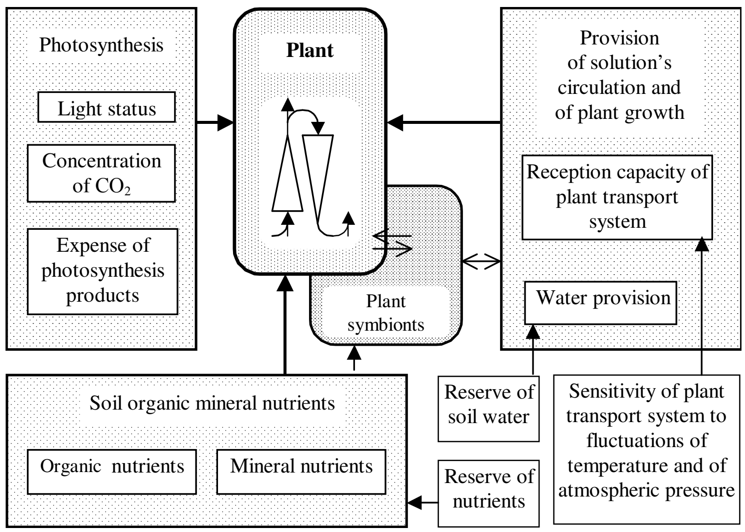

Fig. 5. Components of plant productivity (name of the author: Popov)
Rys. 5 . Składniki produktywności roślin (autor: Popov)

According to our results, soil moisture stock, air temperature and light mode as well as some edaphic factors had greater influence on parent plants than on hereditary generation plant growth.

Theoretical bases of the biological recultivation. The ecological importance of soil organic matter (including humic substances) is first of the supplier of ready complex (difficult) organic molecules, which are consumed and become assimilated by plants; secondly, it, apparently, facilitates transport of inorganic substances in plants; thirdly, a negative allelopatic influence of litter on plant is reduced as a result of humification.

Except the restoration of organic matter in the soil, for functioning "plant-soil" system presence of certain groups of soil biota is necessary (fig. 6). So, the most functional are: a) nitrogen-fixing microorganisms, b) organisms, which participate in transformation of organic material in soil, c) litholytic organisms, which are capable of active biological efflorescence of rock minerals.

We suggest that for real improvement of the functioning of the "plant-soil" system alongside with chemical correction (using of mineral fertilizers) it is necessary to carry out biological correction too (with the purpose of restoration of lost biocoenotic links of ecosystems). The biological correction is a way of management of the functioning of the plant-soil tropho-system. It bases on scientific achievement of modern biotechnologies, such as: vermicultivation (earthworm composting), production of microbiological preparations, biological means of protection of plants etc. The principle of biological conformity lies at basis of such biotechnologies.

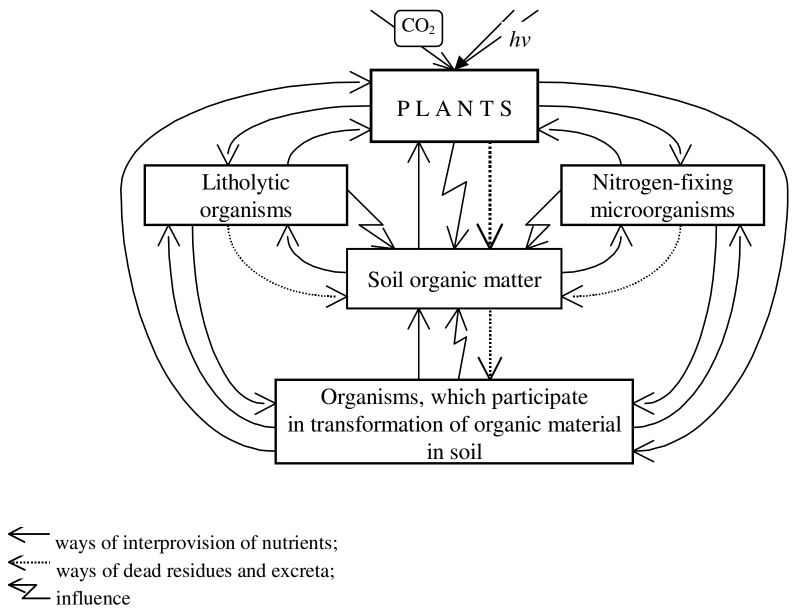

Fig. 6. Trophic mutual relation between plants, soil organic matter and different representatives of soil biota (name of the author: Popov)
Rys. 6. Troficzna wzajemna zależność między roślinami, masą organiczną gleby oraz różnymi przedstawicielami bioty glebowej (autor: Popov)

The basic components of biological correction in the "plant-soil" system are: a) good humificired organic material, containing enough humic substances (for example, earthworm cast composts); b) nitrogen-fixing microorganisms (freely living or living into root-nodules); c) litholytic organisms (for example, mycorrhiza). Besides physiological peculiarity of plants should be taken into account.

On the basis of the offered theoretical bases of biological recultivation it follows that influence on "plant-soil" system should be multiple. The complex of measures should be directed on management of all cumulative "plant-soil" tropho-system.

For more effective ecological modernisation of cereal seed growing we could use the methods of biological correction, exact cultivar selection and agrotechnical measures. The essence of biological recultivation is restoration of the "plant-soil" system functioning. Physiological peculiarity of plants should be taken into account.

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Streszczenie. Badano możliwość ulepszenia nasion na roślinach rodzicielskich *Triticum aestivum* L. oraz *Hordeum vulgare* L. za pomocą różnych czynników ekologicznych. Ustalono, że na dynamikę rozwoju roślin z nasion otrzymanych w różnych warunkach ekologicznych wpływają czynniki hydrotermalne, glebowe i świetlne, a także korzeniowe żywienie mineralne i oprysk. Różnice w chemicznej strukturze nasion nie były znaczne, ale zaobserwowano różną dynamikę rozwoju roślin wtórnych. Podjęto próbę oceny mechanizmu oddziaływania fenotypu rośliny rodzicielskiej na fenotyp rośliny potomnej. Ustalono, że związki organiczne usprawniające transport odżywczych składników mineralnych do roślin rodzicielskich mogłyby podwyższać jakość nasion. Po przeprowadzeniu doświadczenia doszliśmy do wniosku, iż jakość nasion można podwyższyć tylko przez uprawę zbóż, ale tylko wybierając specjalną niszę ekologiczną do uprawy, gdzie można otrzymać nasiona o wysokiej jakości. W związku z tym badanie funkcjonowania systemu "roślina – gleba" oraz opracowanie metod korelacji biologicznej funkcjonowania tego systemu i zwiększenie stabilności jego czynników środowiskowych jest ważnym kierunkiem rekultywacji obszarów zmienionych przez człowieka. Niewątpliwie taka technologia produkcji nasiennej zbóż nadaje się do zastosowania w praktyce.

Słowa kluczowe: poprawa biologiczna, czynniki edaficzne, *Hordeum vulgare,* czynnik hydrotermalny, efekty macierzyste, *Triticum aestivum*