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Influence of the Root and Seed Traits on Tolerance to Abiotic Stress

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Additional information is available at the end of the chapter

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1. Introduction

Relationship between roots and seeds is very important from the physiological point of view.

From the common view, the roots quality is modified by genotype and environmental conditions. But as follows especially from the wheat and other crops analysis the traits of roots are not only under genetic and environment control. Research results confirmed importance of individual seed traits for plant root growth and development, mainly seed vigor and subsequent seedling development at the poor conditions. These results show in all experiments statistically significant influence of abiotic stresses (drought, high temperature) on the seed traits and via the seeds influence on the traits of plant roots.

On the other hand influence of seed quality on the root growth and development of roots quality are basic assumption for the formation of high-quality seed of the most crops in next generation, especially at stress conditions. In the suboptimal conditions, the poor seed quality results in reduced root growth and also in low yield level. When the root growth from the beginning of vegetation is problematic, connected with the wrong roots quality, the negative consequences will continue during the whole vegetation period.

Changes in seed germination during the year exist in some species. Obtained results [20, 21] confirmed statistically significant relationship between speed of seed germination and intensity of geomagnetic activity during a year period.

Long term seed storage conditions influence the following seedling growth and the deterioration speed of the seed stored for a long time is affected by environmental conditions in which the seed was grown. From the practical point of view it is connected with question of the preservation of important genetic resources. Seeds from adverse environmental conditions rapidly lose germination energy and longevity. It can present a

considerable economic costs connected with maintenance of genetic resources. This situation can lead even to loss of genetic resources.

Consequent changes during long term storage consist from: increasing concentration of free radicals, which are formed in time of long-term seed storage, damaging membrane lipids, inactivation of enzymes, damaging storage proteins and DNA. This process resulted to lower seed quality (low vigor) or even total loss of germination. Deterioration of the seeds during storage is irreversible phenomenon, natural for living organisms. Aged seeds influence optimal root growth (angle of root growth in the soil, depth penetration, tillering).

Roots quality influences water utilization in plants with different level by different cultivars in different environmental conditions and by this way drought tolerance during vegetation period and through the new filial seed generation germination and grow of young plants.

The water availability and efficiency of water utilization in time of germination is one of the basic factors influencing field emergence rate. Water uptake is the first step for enzymes activation, and shortly, for successful germination. The large variability in water use efficiency of seeds of different species and cultivars exist.

2. Seed and root phylogeny - general overview

The seeds, roots and their properties are the result of the phylogenic development under stress pressure, especially the influence of dry conditions in time of plant colonization of the Earth. **The seed phylogeny** reflects very interesting historical transition for photosynthetic organisms. The seed history consists of four main steps: the development of seed morphological structures, anatomy of seeds; the development of dormancy and the evolution of seed size (mass) [65, 66]

Seeds were developed over a period of approximately 300 million years of phylogeny for three main reasons [11, 14, 16, 63]

1. increase of species distribution area
2. preserve species for adverse conditions
3. enable efficient reproduction of species

The roots have from the paleontological view the first predecessors in –rhizoids- unicellular “fibres”. [16]

So far, the oldest fossils of these plant organs - real roots came from the period 396 million years ago. As evidence for the findings of the first roots are two plants Rhynia and Sigillaria from the late Devonian period, where paleontological analysis revealed the depth of the roots with length no more than one meter. Plant roots are most sensitive part of plant body. The morphological and physiological root traits respond much more sensitive to the external environment than the aboveground parts of plants. Roots have a large share in the creation of soil, impact on the composition of the micro flora in the formation of ground, humus, the production of carbon dioxide, i.e. the composition of the atmosphere.

Seeds and roots have great importance for the abiotic stress tolerance during vegetation period (drought, high temperature). Seed traits determine plant growth on the beginning of vegetation period; especially by seed vigor, and by seed storage conditions. On the other hand the roots are influenced by seeds quality on the start of plant growth, especially root morphology, i.e. length, surface, deep of penetration of the roots and also root weight, number of root tips, number of root hairs, number of lateral roots and density of roots and modified by environmental conditions. Roots affect plants on the whole vegetation period and from this point of view influence growth and development of new seed generation. The level of these relations depends on the environmental conditions; it means on the influence of seed provenance.

3. Short root and seed history step by step

When we skip the period 3.5 billion years ago, when the cyanobacteria was only on the Earth, the history of the plants can be divided into four periods:

1. Thalassiofyticum- (until 442 million years BC) period of *Algae*
2. Paleofyticum (442-248 million years BC)
3. Mesofyticum (248-97 million years BC)
4. Cenofyticum (97 million years BC until today)

In the first part of **Paleofyticum**, the “*older*” *paleofyticum* (442-354 million years BC) the plants spread from the water on the land. In this time formation of roots started, which enabled to live on the earth's surface. In the “*younger*” *paleofyticum* (354-298 million years BC) is characterized by seed development [16, 63].

The negative impact of environmental conditions -long period of the drought conditions- is reflected strongly in evolution. “*Invention*” of the seeds improved the chance of species survival thanks to the better dispersion of seeds and by this way expansion of the species. The evolution of plants is connected with ability to survive dry and cold period of plant growth. Some mechanisms were evolved, started with tissue specialization, through dormancy evolution to post harvest maturation.

In this period developed psilophyta, pteridophyta and plant ferns gymnosperms. Among the ferns (*Pteridophyta*) are classified plants lycopodium (*Lycopodiophyta*), horsetail (*Equisetophyta*), tree ferns (*Polypodiophyta*) and plants (Progymnospermophyta) as cycads and conifers.

After transition of plants on the earth's surface the influence of abiotic stressors prevail rather than biotic factors. Gradually, however, grew relationship among different species of the plants either negative or positive and between plants and other organisms

In **Mesofyticum** ancestors of the modern ferns appeared (fern seed plants, cycas, benetits, and conifers).

Cenofyticum is the last period of plant development, characterized by spreading of angiosperms. This period lasts until today. As examples there are given three examples of

fossilized seeds (Figure 1, 2 and 3) History of seed development is from the physiological view very interesting [11, 14, and 33]



Figure 1. Fossilized seed, the recognizable is embryo, label (scutellum), and endosperm. Czech Karst



Figure 2. Fragments of fossilised seeds, Czech Karst



Figure 3. Fossilized wallop, Czech Karst

4. Seed development and influence of the seed on the plant growth

The understanding of the relationship between seed development, environmental conditions and seed quality at the molecular, cellular, physiological and agronomical level are basic aim of seed science. On the beginning of seed formation is fusion of male and female gametes and double fertilization. After fertilization relatively short and quick seed development starts, i.e. seed become the primary recipient-sink for assimilates. This process means parallel growth and development of the seed, which includes initial cell formation, development of endoplasmic reticulum and growth of cell organelles – plastids, ribosome's, mitochondria and Golgi complex. After approximately three or four weeks of the seed development, starch and protein granules are main components of endosperm composition. Simultaneously with chemical changes, morphological, anatomical development and quick changes of seed weight occur. Every of these processes can be under influence of abiotic stresses and can be modified in a different way [85].

Development of the most seeds can be divided into three next phases [58]. The first phase is characterized by quick cells division and histodifferentiation to specific part of embryo (cotyledons, growing axis), together with storage tissues (usually endosperm). Next phase is growing phase (expansion) connected with reserves storage (carbohydrates, proteins, lipids) in storage tissues, mostly in cotyledons and endosperm. Whole process of seed development ends by decrease of water content (maturation phase), when seed metabolic activity is reduced and seed is passed to quiescence state (metabolic non-active).

All phases are different in water content at tissues of newly developed seed [59] (Water content increases in cell division phase together with total seed weight. In phase of cell elongation water content is stable, but dry matter of seed increase thanks to stored reserves. Quick decrease of water content characterizes maturation phase, till the level 10 – 15 % of water, specifically for each plant species.

Desiccation phase is typical for orthodox seeds (mostly plants from temperate climate) and necessary for overcoming adverse environmental conditions, evolved as adaptive mechanism in time of plant phylogeny. Thanks to lower water content orthodox seeds can be stored at normal conditions longer time without loss of their quality. This is very important exactly for seeds of plants used as agriculture crops.

Development of seeds and fruits is controlled by phytohormones [57]. After fertilization mainly cytokinins come to action to influence cell division in early stage of seed development. Gibberellins are connected with phase of reserves deposition, when keep endosperm in liquid state thanks to activation of α -amylase [81, 75]. Auxins control cell elongation of newly formed seed. Influence of negative osmotic potential of surrounding tissues, which prevent the embryo to next development [89], is substituted with increase of abscisic acid (ABA) level. ABA suppresses gibberellins' activity in the synthesis of α -amylase and by this mechanism prevents premature germination of new seed [13]. On the end phase ABA level decrease too, together with decrease of water, when the seeds are becoming quiescent. Regulation of ABA level in mature seed determines quiescent or dormant state of seed [79]. During the seed development on mother plant the environmental conditions can change and abiotic stress can appear. Seed development can be aborted in this case, when environmental conditions are very adverse. In early phase of development the embryo is very sensitive to lack of water [29]. Decrease of water potential more than above -1.6 MPa [73] can imply damage of embryo or other tissues. Less favorable environmental conditions can mean only formation of smaller seed, with smaller embryo or storage reserves, but smaller seed size is obviously associated with shorter seed survival [68].

Seed quality is affected by location of seed on mother plant and related with flux of assimilates to seeds. Each seed lot is heterogeneous group of seeds with similar characteristics thanks to the same origin. But if we evaluate each seed in detail, we can find differences between seeds.

Seed quality is influenced by sink: source ratio too. Buds, flowers and siliques of winter rape fall down more from lateral branches than from terminal, which is more preferred [62]. Similarly fruit size decline from margin to the centre of capitulum as the result of resource competition [86, 1]. Found that direct part of sunflower head is supplied from direct leaves. [5] confirm different content of oil, fatty acids and total tocopherol content in different seeds in sunflower head. We can suppose that similar differences exist between each seed in direct content of stored reserves and in synthesis and reduction of phytohormones and other metabolites. Stress conditions in time of seed development can these differences enhance.

All levels of adverse environmental conditions imply induction of stress response. Acclimation starts as the first step, when mechanism of protective compounds synthesis

switches on, for example LEA proteins – dehydrins [32]. Generally scientists agree these proteins play important role in tolerance to water stress. Their protective function consists in stabilization of membrane structures [31, 84]. Angelovici [3] discussed gene expression and metabolic activation during desiccation of seed and their influence to the desiccation tolerance, dormancy competence and successful germination of the dry seeds. Together with genetically conditioned production of osmoprotective substances (as proline at rape tolerant to salinity [70] the maternal effect applies role in adaptation to environmental conditions too [46, 47, 88]. Dyer et al. [40] confirm the seed adaptation of some invasive species to adverse conditions in germination time on the mother plant in time of their maturation. They think that transgeneration plasticity (TGP) of seeds is the result only just seed adaptation on stressed plants. TGP can explain phenotypic move in adaptability of plants to worse environmental conditions and influence by this way more easy spread of species in environment.

The participation of environmental conditions on development of viable seed is generally taken to consideration; this influence can be even significant. When the stress conditions are continuous, developing seed can be damaged and on macroscopic level it means higher occurrence of less vigorous or even non-germinated seeds. In slightly adverse conditions protective compounds accumulate in seed and stay stored inside after desiccation. It has also been demonstrated that in seed stored rather than de-novo synthesized mRNAs play key roles during germination

The influence of seed on plant individual is formed in time of seed development on mother plant. Seed quality affects the germination process, which can be modified strongly by environmental conditions and next development of plant. The seeds germination is a complex physiological process comprising many metabolic pathways [66] with the goal to originate new plant as the next generation of plant species). Germination starts with uptake of water to the dry seed by imbibition, followed by metabolic changes in seed and ends with rupture of covering layers and emergence of radical protrusion. Figure 4 shows the example of the seed provenance on the root system of juvenile plants.

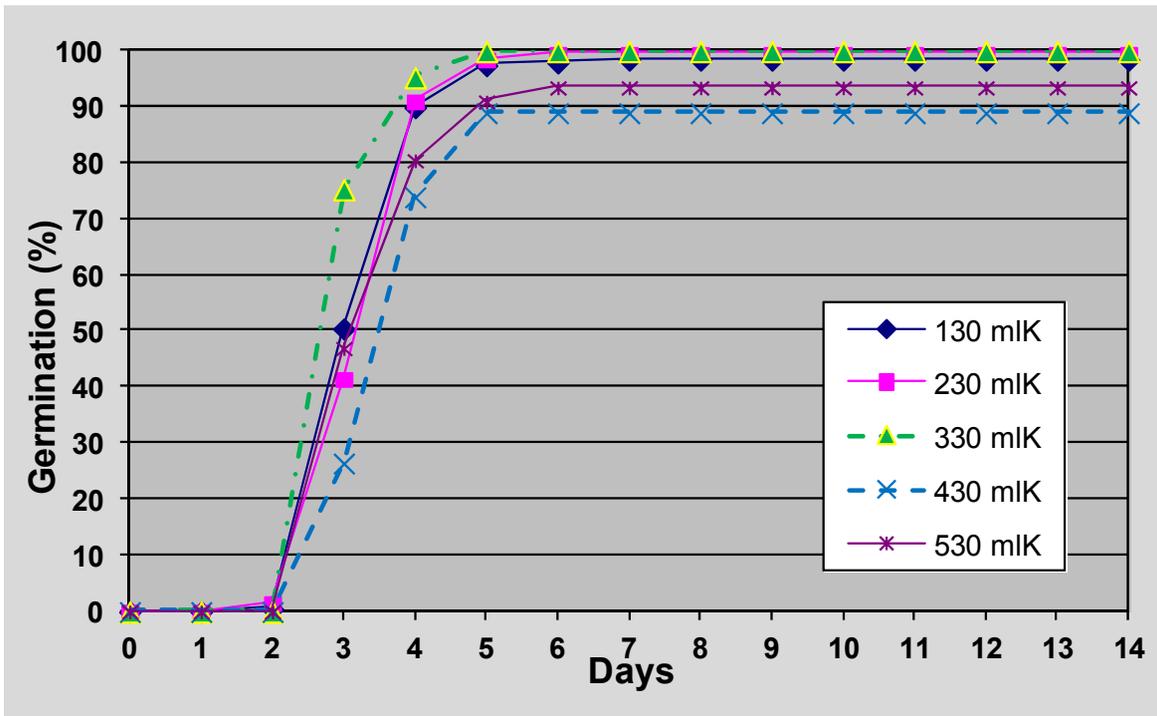
Ability of seeds to germinate in adverse environmental conditions is expressed as seed vigor can be explained as difference between germination percentages analyzed at optimal conditions by laboratory tests and between percentages of seedling emergence in field conditions (field emergence). There is lot of reasons for this difference (diseases, soil conditions, water content in soil, variability of temperature in the soil, etc.).

The influence of the seed provenance together with cultivar is very important. For example, the obtained results from the experiment with the organic and conventional seeds (four different provenances) of various spring cereal cultivars (bread and emmer wheat, *Triticum aestivum* L. and *T. dicoccum* Schrank, barley, *Hordeum vulgare* L. and oat, *Avena sativa* L.) confirmed importance of the cultivar and the seed provenance for the seed quality especially for the germination and efficiency of water utilization during this development phase. This is very important factor because of seed biological quality is one of basic factors, which has influence on the growth and development of the filial generation, especially in drought

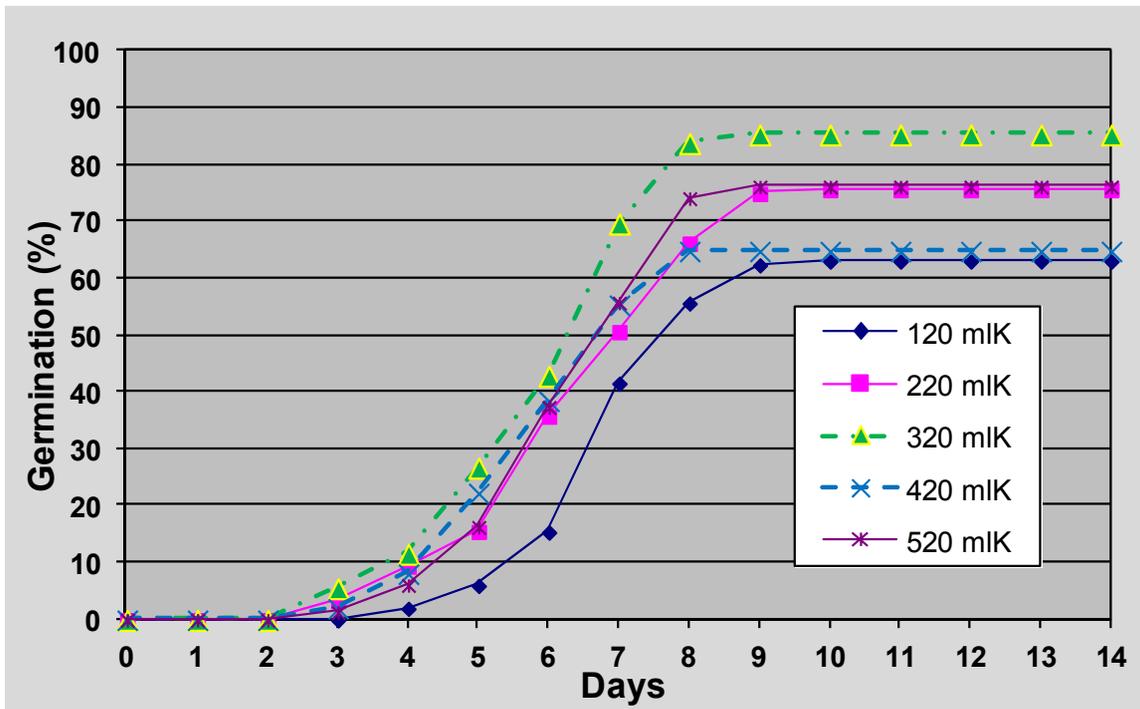
conditions [24] Good established crop stand is the basis for optimal development of agriculture plants to obtain next generation of seeds with high quality [76]. On figure 5 and 6 are examples how the seed provenance influences the germination process. Comparison of wheat plants from different seed lots is on the figure 7.



Figure 4. Example of seed provenance (variety Imari) effect on the root system at soya. On the left: from the seed from the dry conditions; on the right: seed from the standard environment. Influence of the seed provenance on the number of lateral root branches is evident



A



B

Figure 5. Difference between five spring barley seed lots germinated in standard (Fig A, filter paper, 30 ml of water, upper part) and in dry (Fig B, sand, 20 ml of water, lower part) conditions. Seed lots quality (expressed by germination curves and germination energy) looks very similar in optimal conditions, but can be very different in stress (drought) conditions. Difference of seed lot 3 (green) is evident.

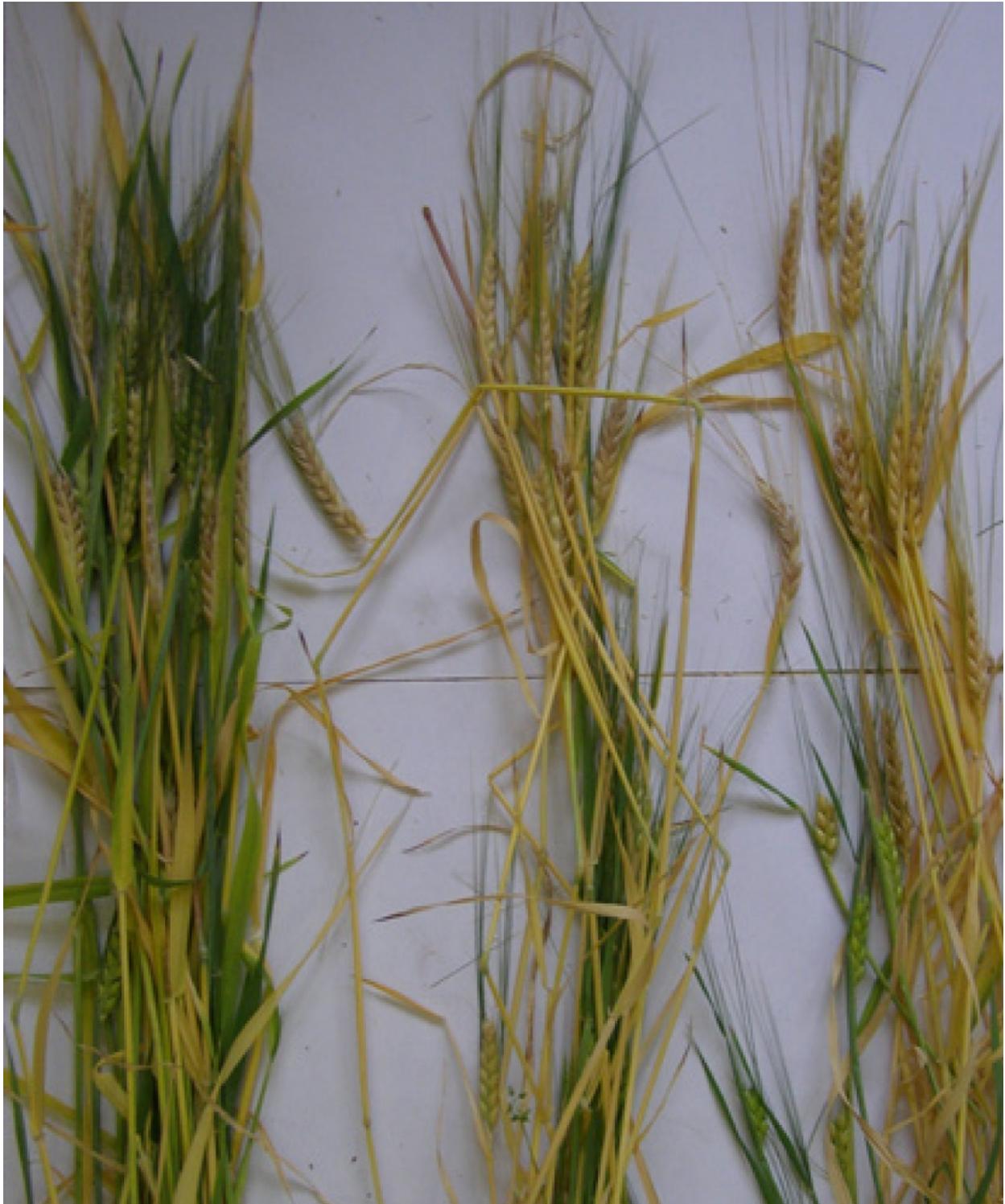


Figure 6. Wheat plants grown in containers. On the left plants from the certified seeds obtained from the seed company; on the right two plants from different FSS (farmer save seed).

5. Importance of root traits for the seed growth and development

Quality and physiological activity of the roots is necessary condition for growth and optimal shoot development and subsequently development of the seeds with good quality at the majority of the field crops. This relation is also valid vice versa - the seed quality has positive influence on the root growth and development. Growing environmental conditions (=provenance), especially drought and high temperatures affect basic metabolic pathways, chemical composition of seeds, seed traits and traits of sprouting plants rootlets. These changes of the seeds are connected with efficiency of water utilization and especially with development of the root system. The research results show relatively large influence of seed traits on the root development. The genotypes with good germination under unfavorable conditions develop larger root system in field conditions, i.e. volume, length, deep of roots penetration after sowing and also during following vegetation period [17, 18, 19, 22, 28].

Coming climate change influencing mainly the variability of weather conditions during the vegetation period will increase the importance of the root system as the factor which plays more and more important role in the above-ground production and seed production too.

The importance of the seeds and roots are still neglected in the plant production. Misunderstanding of the roots importance can be found in the lot of scientific works, where detailed statistical analysis often evaluate only in above-ground parts of the plant physiological, anatomical, morphological and other properties, their relationships, but without knowledge about influence of the root system on the shoot analyzed traits and their relations.

Physiologically, the roots are the most sensitive part of the plant. As follows from the physiological literature, the basic changes of root system thanks to environmental conditions have following general way and influence: Drought changes deep of root penetration, low pH has influence on the length of roots, influence of salinity depends on the salinity type, high temperature influences number of root branches, low nutrients level is connected with the increase of the root system length, decrease of roots volume and number of branches, combination of abiotic stresses has large influence on the decrease of every trait, but not in every type of environmental conditions. These types of changes can have influence on transport of water and metabolites in plants and also on the shoot and seed growth and development. The developmental and growth stage, in which stress appear is very important. It is possible to show this on the rapeseed [17,18].

The speed of the root growth initialization after the winter period and the change of the ratio between dry weight of roots and above-ground parts in favor of the root mass in dry conditions during the vegetation period had the greatest impact on drought tolerance and yield of rapeseed. (The spring regeneration is expressed by the ratio of the dry weight of roots in spring and autumn. The variety with the largest growth rate of dry matter to roots has the seed production with best seed quality, i.e. weight, vigor, germination, optimal chemical composition).

Darwin expressed that "Roots are as brain of plants" [34], i.e. roots can be taken as a similar body like the brain. Currently, it is known that for the transmission signals (changes of potential) between root and above-ground plant parts plasmodesma are needed and there seems to be an important role for auxin molecule (IAA). For example, information about pathogen attack or strong physical stress can be quickly transmitted from the roots to the other plant parts in order to begin start as soon as possible organism defense thanks to plasmodesma. The genes for some plasmodesma proteins that form the connections are similar to the neuron proteins. The root system has the role as control centre with rapid transmission information to other plant parts. New situation creates a certain type of synapses, which are to some extent „the plants memory“, i.e. certain type of reaction to already known situation. If the stress is repeated again, the reaction of the plant is more rapid on the basis of this memory [2, 4, 6, 7, 8, 9, 10, 11, 30, 56, 69, 80, 82, 83, 87, 91]. It is also known that root apices during growth can recognize in advance dangerous soil substrate and avoid them using similar active avoidance root tropism.

Biochemical pathways - root influence of the shoot

Last, but not least, there are significant advances in ecological studies, behavioral studies, on memory and learning phenomena in plants. **Baluška in his work gives a very detailed interpretation (verbatim quotation)** [6]. *"The plant neurobiological perspective reveals several surprises when the classical plant hormones like auxin, abscisic acid, ethylene, and salicylic acid are considered from this angle. Auxin and abscisic acid elicit immediate electric responses if applied to plant cells from outside, suggesting that their regulated release within plant tissues may be a part of neurotransmitter-like cell-to-cell communication. Abscisic acid signaling pathway is conserved between plants and animals and this signalling molecule both stimulates and is endogenously produced in human granulocytes in a way suggesting that it acts as endogenous proinflammatory cytokine. Biologically active abscisic acid was isolated also from brains of vertebrates indicating possible roles of abscisic acid in the central nervous system. Salicylic acid activates similar subset of MAPKs as voltage pulses. Ethylene, a classical plant hormone, is an anaesthetic, a fact that plant physiologists have ignored until now. Interestingly, anaesthetics used on animals including man, induce anaesthetising effects on roots similar to those of ethylene. Ethylene is released in mechanically stressed plant tissues, and structurally diverse anaesthetics activate mechanosensitive channels. As ethylene is released after wounding, it might act to relieve 'pain' in plants. There are numerous other plant-derived substances, which manipulate the pain receptors in animals, such as capsaicin, menthol, camphor. Interestingly, the monoterpene volatiles, menthol and camphor induce oxidative stress and inhibit root growth in maize, indicating that they, too, act as plant signalling molecules. Finally, plants express inhibitors that are specific to the neuronal nitric oxide synthases. Another example of neuronal-like behaviour of plants is the report that prevention of nyctinastic movements of leguminous leaves causes their death while leaves allowed to 'sleep' stayed healthy. This resembles the situation in animals. Although melatonin was discovered in plants more than ten years ago, we know almost nothing about roles of melatonin in plants despite the fact that it is biochemically closely related to auxin. Interestingly in this respect, melatonin mimics auxin in the induction of lateral root primordia from pericycle cells."*

6. Influence of the seed traits on the root growth and development

Introductory notes

Higher plants play the most important role in keeping a stable environment on the Earth to regulate global environment by many ways in terms of different levels molecular, individual, community, and so on [49,50], but the nature basis of the mechanism is gene expression and control temporally and spatially at the molecular level. There are many adverse stress conditions in the continuously changing environment, such as cold, drought, salinity and UV, which influence plant growth, development and crop and seed production.

Environmental conditions during the growing season affect biological quality of the evolving seeds, i.e. chemical composition of seeds, anatomical and morphological seed traits and traits of sprouting plants - basic metabolic seed pathways. Generally is known that the biological quality of seed is also one of basic factors, which influences growth and development of the roots at beginning of the filial generation and during vegetation period. It is possible to conclude that there is significant indirect influence of environmental conditions through the seed traits on the root development.

After harvest seed should be stored, i.e. there are storage conditions, which also affect the properties of seeds (enzyme activity, formation of free radicals).

The seed traits and traits of sprouting plants affect in filial generation especially root morphology at begin of vegetation period: length, surface, deep of roots penetration and also root weight, and later also number of root tips, number of root hairs, number of lateral roots and density of roots. Crop emergence, especially with good roots then influences the further course of growth. The start of period has significant influence on the following growth.

So far obtained results confirmed also in all experiments statistically significant influence of abiotic stresses (drought, high temperature) on the traits of seed and via the seeds influence on the root and shoot traits at begin of vegetation period. Very similar results among analyzed field crops in all types of experiments were obtained [17].

This physiological phenomenon - germination (1) is influenced by the environment conditions during germination, during vegetation period and in time of new seed formation (2) and during new seed germination and growth (3). Resistance or tolerance to the environmental influences is (4) hereditary phenomenon.

1. Germination

Uptake of water

Uptake of water by mature dry seed is triphasic: I - rapid initial uptake (imbibition), II - plateau phase (metabolic processes) and III - this phase occurs when germination is completed. This phase is inhibited by the plant hormone ABA. The interactions between abscisic acid (ABA), gibberellins (GA) and brassinosteroids (BR) are regulating key

processes that determine dormancy and germination. Abscisic acid inhibits germination and gibberellins and brassinosteroids promote germination.

The first phase of germination If the seed gets into the soil initially only water uptake exist, which start the first stage of germination, i.e. anaerobic processes, which is separated from embryo germination and for which there isn't need oxygen. This phase is mostly regulated by the amount of water in the seed, temperature and takes 24 -36 hours. Exactly imbibition phase is regulated only by differences in water potential between seed and soil. For example, in wet salted soil amount of water accessible for seed can be low, thanks to low water potential of soil than seed. Anaerobic respiration is predominant in this phase - the biological activity without oxygen (for example alcohol dehydrogenase activity).

The processes in the first phase can be affected by storage method, which affect the structural changes in the seed. Seeds of some varieties may then quickly absorb water, but in the case of drought loose of water is quicker too.

But transition from phase to phase is not sharp, for example embryo of maize seed can be highly hydrated and endosperm have low amount of water. On the other hand, activation of mRNAs in wheat seed was detected 2 hour after start of imbibition.

The second phase of germination is also under influence of the seed storage way, prolonged storage significantly affect mainly structural changes in the seed membranes and reduced enzyme activity. The manifestation of this changes may be, for example, decrease of germination energy (early germination) resulting in a field conditions in the low field emergence). In this phase begin - aerobic respiration system, citrate cycle, oxidative phosphorylation, and rapid activity of the mitochondria and lot of other biochemical processes. The visual germination process begins. What happens during germination? Metabolic activity in seed increases sharply, lipase, α -amylase, protease and peptidase - hence they are broken down starches, proteins, lipids, and their metabolic products are transported through the scutellum to the sprouting embryo - germination begins. Prerequisite for good germination is low ABA levels, which resulted in the loss of dormancy and increase the concentration of gibberellins thus promoting hormones, which creating α -amylase that breaks down starch.

Germination process according to the latest information also contributes brassinosteroids. Interactions between abscisic acid (ABA), brassinosteroids and gibberellins (GA) determine the level of dormancy and germination energy. These plant phytohormones (GA) with many functions in the plant during germination and seed sprouting are produced and through label penetrates the endosperm to the aleurone layer, where it promotes the synthesis of α -amylase, thus accelerating the starch breakdown. The ratio of starch, damaged starch, lipids and proteins like macro-elements can affect the germination rate.

Water uptake and efficiency of the water utilization are essential for enzyme activation, i.e. for use of reserve seed storage material [23, 24, 25, 26]. This trait has also influence on the root development at the begin of the vegetation period, but there is large variability in water use efficiency of seeds between different species, cultivars from different conditions (seed

lots) and even between individual seeds from one seed lot [17, 19, 35, 36, 37, 38, 39, 40]. From the common view, the quality of root is modified by genotype, by environmental conditions and also by seed traits, especially thanks to seed vigor and young plants traits, especially at the poor conditions.

2. Stress during vegetation period

Water utilization by plants during vegetation period influences chemical composition of seed, but also traits of young plants in filial generation. The availability of water and efficiency of water utilization during germination is one of the basic factors that influence field emergence rate and following plantlet and plant root growth. The large variability of water use efficiency of seeds of different species and cultivars exists. This trait is under genetic and environmental control.

For each type of stress that acts on the developing seed the different changes in subsequent generation exist. So far obtained results confirmed that changes in the root system have resulted not only in changes in nutrient uptake, but may be reflected in the final stages of plant development and yield. In the case of nutrient uptake can be observed significant cultivars differences. The largest differences in nutrient uptake between the standard environment and stress environment (drought, high temperature, low pH) is previously in micronutrients (especially Zn, Mn, Fe), minor differences were then at macroelements (N, P, K, Ca, Mg). These changes may affect at more sensitive cultivars seeds properties.

In case of abiotic stress obtained results confirmed statistically significant influence of abiotic stresses at environmental conditions on the seed traits [27, 78]. These seed traits have a substantial effect on the tolerance to analyzed abiotic stresses in the filial generation and also on the root system and water utilization during germination. Similar results for spring and winter wheat were obtained [27, 78]. For example, severe stress during seed filling caused soybean plants to exceed their capacity to buffer seed number, shifting seed weight distributions towards a larger proportion of small seed, resulting in poor seed lot germination and vigor [39].

Stress during vegetation period for most crops changes anatomic structures of caryopsis. The most significant are changes in the layer of the pericarp, which creates a large number of cells which are different in size and shape. Seed anatomical changes are in accordance with the change of caryopsis morphology. Changing the aleurone layer structures can greatly influence the properties of all the economically important seed. This phenomenon highlights the importance of regularly exchange seed in crops production.

The influence of the environmental conditions changes energy content of the seeds. Grain influenced by abiotic stress is usually less vigorous compared with non-stressed plants. Seed vigor is also associated not only with weight, chemical composition, phytohormones activity, but also with change of the embryo properties. Negative influence of drought and high temperature conditions is reflected in the content of energy-rich substances

accumulated in grain and straw, which are given not only the process of photosynthesis, by transport in plants, but also by the ratio and content of energy-rich substances, particularly sugars, proteins and fats.

High temperature stress of *Brassica napus* and other crops during flowering reduces micro and megagametophyte fertility, induces fruit abortion, and disrupts seed production [64].

3. Stress during new seed germination - seed stress tolerance

It is known that it is possible to provide selection for cultivar resistance to stress already at the seed and at the seed germination stage and on the quality of the plant root system. Quality of the embryonic roots is important for the following growth and also roots development. In the juvenile phase and in later stages, these are the same genotype! This is a general biological regularity. At each experiment very good relationships between above named traits exist.

For example it is possible to determine the genetic relationship between salt tolerance during seed germination and vegetative growth in tomato by comparing quantitative trait loci (QTLs) which confer salt tolerance at these two developmental stages. However, simultaneous improvement of tolerance at the two developmental stages should be possible through marker-assisted selection and breeding [43, 44].

Germination is also regulated by abscisic acid content. The content of abscisic acid in the seed is determined by genotype and conditions during the growth of seeds [78].

Signal transduction pathways, mediated by environmental and hormonal signals, regulate gene expression in seeds. Seed dormancy release and germination of species with coat dormancy is determined by the balance of forces between the growth potential of the embryo and the constraint exerted by the covering layers, e.g. testa and endosperm. GA releases dormancy, promotes germination and counteracts ABA effects. Ethylene and BR promote seed germination and also counteract ABA effects. We present an integrated view of the molecular genetics, physiology and biochemistry used to unravel how hormones control seed dormancy release and germination.

There are several ways to improve the adaptability of plants to the variable environmental stress conditions. Physiological studies of plant integrity have shown that the plant responds to stressors by modifying more than 100 physiological traits. The presented results [26] confirmed that seed vigor and plant vigor (quick escape from any stress) are in significant correlation with yield and root quality system.

Selected basic traits of seeds (vigor, germination percent, and emergence) and especially stress tolerance during germination of the seeds to the high and low temperature during day and night have significant influence on the quality of the root development. Plants with well-embryonic roots and high energy potential germination escape the stresses during begin the growing period, especially at drought conditions and are guarantee with high probability quality of the root system [64, 78,90].

4. Heredity, the availability of a selection at the level of seeds and seedlings

Contemporary knowledge confirm possibility of making selection for the root system and stress root tolerance on the basis of seedlings stress tolerance, i.e. at time of the sprouting. It is possible also to evaluate characteristics of seeds and seedlings, i.e. provide selection, after plant hybridization of the plants on the basis of the seed and seedlings traits for the seed quality an also for the classic selection in the plant breeding.

Seed of BC₁ progeny of an interspecific cross between a slow germinating *Lycopersicon esculentum* breeding line (NC84173; maternal and recurrent parent) and a fast germinating *L. pimpinellifolium* accession (LA722) were evaluated for germination under cold stress, salt stress and drought stress, and in each treatment the most rapidly germinating seeds (first 2%) were selected [43]. The results confirmed that rapid seed germination under a single stress environment may result in progeny with improved seed germination under a wide range of environmental conditions. Seeds of F₂ progeny of a cross between a slow-germinating (UCT5) and a fast-germinating tomato line (PI120256) were evaluated for germination under non-stress (control), cold-stress and salt-stress conditions, and in each treatment the most rapidly (first 5%) germinating seeds were selected, grown to maturity and self-pollinated to produce F₃ progeny.

In the case of phytohormones content that are genetically controlled by genes and it is not possible to draw any general conclusion about the correlation between the hormones content and the germination capacity during sprouting stress tolerance and water uptake. Why? Because all authors differ in their results and in conclusions; on the other hand it is possible to read that the fact that the sensitivity of the tissue towards hormones is also a very important factor in the development of regulation. High temperature stress during seed filling in controlled environments reduces soybean [*Glycine max* (L.) Merrill] seed germination and vigor, but the effect of high temperature in the field has not been determined. Contemporary findings support the results of experiments in controlled environments by demonstrating that high temperature during seed filling in the field, without seed infection with *P. longicolla* or physical injury, reduced soybean seed germination and vigor. Influence of the seed traits on the root system is known; especially at begin of vegetation period. Quality roots during the growing period are assumption for the creation of high-quality seed at most crops. *This relationship exists in reverse*. In the suboptimal conditions, the poor quality of seeds result in reduced growth and performance, quality and variety of the health of crops. When growth is at the beginning of vegetation period has the bad quality of embryonic roots according to bad seed quality in the suboptimal field conditions, the negative consequences are during all the vegetation period [27, 40, 48, 64, 71, 77, 78].

The root system can be affected by the quality of seeds especially at begin of vegetation period and change The worse seeds in stress environment can affect not only the quality of the root system with all the physiological consequences, *but also in some cases at some characteristics* subsequent generations, especially at the morphologic traits. If the combined effects of stressors during development and growth of seeds influence the subsequent

generation through the seed traits it becomes especially at seedling traits and weight loss and mostly at the root system. This change is also at the chemical composition of the seeds. This phenomenon is still neglected in the plant breeding.

7. Conclusion

Development of the roots took place after the relocation of the plants to the surface of the Earth, i.e. long time before development of the seeds. The reason of the seeds development in the later time is to preserve the species, spread species and survive in unfavorable conditions (particularly by the development of dormancy). Importance of root traits for the seed growth and development is very significant and these relationships exist also in opposite direction - seed traits have influence on the root development. Seed quality is affected by location of seed on mother plant, by environmental conditions and by storage conditions.

The roots are, from the physiological view the most sensitive part of the plant. The root system has the role as control centre with rapid transmission information to other plant parts ("plant brain").

It is possible to provide selection for cultivar resistance to stress already at the seed germination stage and on the quality of the plant root system. Quality of the embryonic roots is important for the following growth and also roots development. In the juvenile phase and in later stage, there is the same genotype! This is a general biological regularity in nature.

It is also possible to evaluate characteristics of seeds and seedlings, i.e. make selection at this developmental phase, after plant hybridization on the basis of the seed and seedlings traits for the seed quality and also for the classic selection in the plant breeding.

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