INFLUENCE OF ABIOTIC STRESSES ON THE YIELD, SEED AND ROOT TRAITS AT WINTER WHEAT (*TRITICUM AESTIVUM* L.)*

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Divergences of sensitivity of different winter wheat cultivars – Astella, Estica, Ilona, Samanta, Olga, Patria, Plodna, Šárka – to abiotic stresses, i.e. to standard level of nutrients, low level of nutrients, drought, drought and low pH, drought and high temperature, combination of drought, high temperature and low pH, were analysed. The choice of experimental environments represents the basic soil and climatic stress conditions of the Czech Republic. Abiotic stress factors affect significantly yielding traits, root traits, seed traits and in the next generation traits of sprouting plants – especially root morphology: number of root tips, number of root branches, length of the root system. The three cultivars – Patria, Olga and Samanta – are cultivars with good tolerance to abiotic stresses. On the other hand, Plodna and Estica are two cultivars with lower tolerance to the abiotic stresses. Statistically significant differences ($P < 0.05$) among analysed cultivars were only in four traits: harvest index, number of spikelets per spike,weight of thousand grains and length of spike. These are the results of relatively strong stress effect. It is evident from the results with combustion heat calorimetry, that seed stock produced from plants grown under abiotic stress conditions, decrease very significantly the amount of energy in 1 g of dry matter, which shows up in the following generation decrease of germinating power and changes in plant growth. There is a possibility to conclude that the sensitivity of winter wheat cultivars to abiotic stresses is very important traits in plant production. The tolerance of cultivar to abiotic stress is under genetic control. The improved response of cultivars to stress conditions is available via plant breeding.

abiotic stresses; seed traits; yield traits; root development; calorimetry; cultivar differences

INTRODUCTION

The ability of plants to develop response to adapt to environmental stress situations, is exceptional in biological world. To obtain a profitable production well adapted to the demand of the market and for industrial uses, careful choice of varieties and of crop management is needed. The development and production of seeds depends upon series of phases: initiation of reproductive structures, the production of flowers, pollination, fertilization, seed development and seed filling. The physiological processes involved in these phases determine the success of seed production.

Seed testing in agriculture has been usually composed of several factors. The analysis of the seed vitality of different winter wheat cultivars in determining response to stresses and analysis of seed vigour for development and yield of the different cultivars under field conditions is a serious problem of agronomy. A study of the interrelationship between different phases of reproductive growth can give information on the relative strengths of reproductive and vegetative sinks, the extent competition between reproductive and vegetative organs for assimilates under stressed conditions and effects on seed yield and quality. One of very dominant essential problems stress factors leads to the reduction of seed biological value and performance of progeny generations – especially traits of root. Stress abiotic factors (drought, high temperature, low level of nutrients, low pH...). affect the seed quality, seed morphological, physiological and biochemical traits, performance of progeny generations, water uptake, plant development, yield formation and especially basic root traits: root length, root surface, root weight, nutrient uptake, number of root tips, number of lateral roots and root density.

Abiotic (and also biotic) stress effects can be observed during seed production, at harvesting, during seed drying, during storage, during classification, during seed coating, packaging and transportation. It has been concluded, that abiotic and biotic stresses during seed production and processing affect seed quality, performance and can influence the following phases of seed processing during seed propagation or maturation in various climatic conditions and during industrial processing. Regulation of seed traits, seed vigour and traits of roots of sprouting plants is the main aim of seed physiology.

Shortage of nutrients in the soil leads neither to the decrease of basic physiological processes of plants (photosynthesis, transpiration), nor it also affects the biological quality of seeds. One of the elements, which participates in the final quality of seeds, is nitrogen (Hnilička, Novák, 1998b; Hnilička, 1999). It is one of the

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limiting factors of the seed quality, as its shortage, as well as its oversupply in the soil test leads to the decrease of agricultural crop seed viability. Besides the decreasing ability of germination the shortage as well as of nitrogen necessitates the decrease of rich – in – energy assimilatory products translocation into seeds, but this relation has not been explicitly described in literature review. It has been stated, that the content of energy related to 1 kg of applied nitrogen decreases linearly with increasing doses of nitrogen (Hansen, Diepenbrock, 1994). On the other hand it can be said that the content rich in energy assimilates in wheat does not react to dose changes of nitrogen fertilization (Bláha et al., 1998; Hnilička, Novák, 1998a; Hnilička, 1999).

The contemporary seed science has the following principal goals: 1) To quantify the important stresses which influence the seed yield and seed quality within crops. 2) To identify the stages of reproductive development at which stress influences the seed yield and seed quality. 3) To develop methods to measure and quantify stress. 4) To quantify the genotypic variation in response to stress. 5) To investigate the physiological basis of the variation observed within vegetable crops. The basic aim of the presented work was to analyse cultivar differences of influence of abiotic stresses on the yield traits, seed traits, net energy content and influence of seed traits in the following generation on the germination of seeds and root development.

MATERIAL AND METHODS

The eight winter wheat cultivars of *T. aestivum*, different from morphological, physiological and anatomical view, registered in the Czech Republic and in Poland – Astella, Estica, Ilona, Samanta, Šárka, Olga, Patria, Plodna, selected to represent the range of field tolerance to drought and high temperature, were used in pot greenhouse experiments. The responses of wheat cultivars to different abiotic stresses and their combination were analysed in pot experiments using mixture of soil (50% of soil, 50% of sand). Plant treatments (15 seeds per pot, 10 repetition per variant, 3 year experiments) during experiments were: standard level of nutrients, i.e soil content of nutrients was similar to Knop nutrient solution by adding of nutrients to the mixture of soil and sand (SN), low level of nutrients – 50% of standard level of nutrients (LN), drought (D), drought + low pH (D + pH), drought + high temperature (D + HT), drought + high temperature + low pH (D + HT + pH). The choice of experimental environments represents the basic soil and climatic stress conditions in the Czech Republic. In all the outlined experiments the same seed stock was used and the chosen varieties had different pedigrees in order to avoid the influence of common parents. The soil was taken from the field, with similar physical structure, nutrient content but with different pH. The basic experimental conditions as a model represent relatively strong influences of abiotic stresses. The basic experimental conditions are presented in the following survey:

Type of stress	Temperature/night	Temperature/day	Soil moisture*	pH soil
Standard conditions	15 °C	20 °C	70	6.5
Low level of nutrients	15 °C	20 °C	70	6.5
Drought	15 °C	20 °C	40	6.5
Drought + low pH	15 °C	20 °C	40	4.5
Drought + high temperature	20 °C	35 °C	40	6.5
Drought + high temperature + low pH	20 °C	35 °C	40	4.5

* % of soil capacity

In low pH experiments pH factor was continuously measured. Low pH in soil was prepared by 0.2% solution of H_2SO_4.

After the harvest of the basic experiments with stress conditions the analysis of main yield traits was provided. The next step was the analysis of development of the root system in the following generation after the influence of abiotic stresses. For this purpose the following stepwise analysis was applied.

Seed surface was sterilised in 1% $CaOCl_2$ for 5 minutes. After rinsing with deionized water, the grains were used for laboratory experiments. Plants were cultivated under standard conditions in standard growth chamber. After 5 days of germination at low temperature (5 °C) in growth chamber with a day-night period 18 hrs and 6 hrs. Average representative standard sprouting plants were selected. Environmental conditions were maintained at 20 °C at day, 15 °C at night, 18 hrs light and 6 hrs darkness. The light intensity was 490 $\mu mol.m^{-2}.s^{-1}$. The light source was sodium 400W discharge lamp. Five replications of the experiment were provided. Fifty plants per replication were analysed. Plants were grown in circulating nutrient Hoagland's solution III. At harvest of measured plants – three weeks after the beginning of growth in growth chamber, plant shoots were separated from the roots and different parameters of shoots and roots were measured by standard methods: dry matter of roots and shoots, length of roots, volume of roots, root morphology, total length of main roots, shoot : root ratio and nutrient uptake. The presented data of experiments are means of four independent experiments. The images 800 x 600 pixels were analysed by the image analyser LUCIA (Laboratory Imaging Czech Republic). For segmentation of picture by thresholding both original images (for detection of thick roots) were used. The length of the root was estimated as a half of perimeter of the projected image measured by line interception methods.

In case of analysis of net energy content we observed the influence of abiotic factors on energy amount accumulated in 1g of dry matter of vegetative parts and grains during ontogenesis, above all in full ripeness. Heat combustion values were measured with the automatic dry combustion calorimeter MS 10 A of the German firm Laget. We recounted the obtained values per 1 g of dry matter ($kJ.g^{-1}$ of dry matter) by CSN ISO 1928. The results were evaluated statistically.

Table 1. Average values of all cultivated cultivars across all treatments (environments)

Environment	W1P	NSP	WGPS	WTG	LS	NSPS	NGS	WGPP	H.I.
S	5.997[b]	2.845[a]	1.021[b]	30.201	38.31[d]	18.497[b]	34.862[a]	2.904[a]	0.481[c]
LN	5.181[b]	2.085[b]	0.993[b]	32.608	33.986	18.067[b]	27.444[b]	2.070[b]	0.438[c]
D	1.117	1.030	0.581[c]	37.415[c]	27.921	13.550	15.323[c]	0.596	0.503[c]
D + pH	1.600	1.230	0.557[c]	30.526	29.373	14.883[c]	17.895[c]	0.550	0.431[d]
D + HT	0.815	1.250	0.203	24.895	27.108	12.808	6.847	0.232	0.288
D + pH + HT	0.675	1.038	0.191	26.951	29.532	12.485	6.777	0.187	0.271

$P < 0.05$
a = simple contrast with: 2, 3, 4, 5, 6
b = simple contrast with: 3, 4, 5, 6
c = simple contrast with: 5, 6
d = simple contrast with: 5
W1P – weight of one plant (g)
NSP – number of spikes per plant
WGPS – weight of grain per spike (g)
WTG – weight of one thousand grains (g)
LS – length of straw (cm)
NSPS – number of spikelets per spike
NGS – number of grain per spike
WGPP – weight of grains per plant (g)
H.I. – harvest index
S – standard level of nutrients
LN – low level of nutrients
D – dry conditions
D + pH – dry conditions and low pH
D + HT – dry conditions and high temperature
D + pH + HT – dry conditions and high temperature and low pH

Table 2. Influence of abiotic stresses and their combinations on the length of the main root of winter wheat

	S	LN	D	D + pH	D + HT	D + pH + HT
Astella	11.88	13.81	18.89	18.79	13.24	14.51
Estica	11.25	14.67	18.87	18.69	13.35	13.68
Ilona	11.21	13.90	17.95	18.31	13.90	13.41
Samanta	11.90	12.41	17.98	18.40	14.20	13.91
Olga	11.30	13.90	18.20	18.05	14.11	13.90
Patria	12.32	13.40	18.05	18.40	14.04	13.30
Plodna	12.00	12.50	18.30	18.40	13.91	13.25
Šárka	11.90	12.40	18.00	18.35	14.00	13.20

Abbreviation see Table 1
LSD-5% 3.25 cm

RESULTS

It was concluded on the basis of analysis of yield traits, that there was a very important influence of abiotic stresses on the measured traits. Relatively great differences in measured traits between standard and stress conditions were obtained. For each type of stress different type of change of measured trait was obtained. On the basis of statistical analysis of variance (ANOVA), it was concluded that significant differences for measured influence of abiotic stresses (and their combinations) exist. Statistically significant differences ($P < 0.05$) among analysed traits of cultivars were only at some of measured traits. It is the result of utilisation of relatively strong stress effect.

The obtained results of influence of abiotic stresses and their combinations on the yield traits were summarised in Table 1. It is possible to conclude, that relatively great influence of abiotic stresses on the traits of yield exist. For every type of stress factor (or combination of stress factors) there is a typical reaction of analysed cluster of cultivars. It is a common reaction. But in the case of analysis of reaction of individual cultivar, there is a possibility to conclude, that for every type of stress factor and for each cultivar a special response of every cultivar exists. In the case of analysis of individual cultivars, on the basis of the change of root traits in stress conditions, on the basis of the variability of seed traits and traits of yield in stress conditions, it was possible to conclude that the three cultivars, i.e. Patria, Olga and Samanta are the best tolerant cultivars to abiotic stresses in analysed group of cultivars. On the other hand, Plodna and Estica are two cultivars with low tolerance to the abiotic stresses in measured group of cultivars. There is also a possibility to conclude, that the influence of abiotic stresses has a very important influence on the root system development. The importance of individual traits of seeds and especially of roots for plant production is based on the genotype and at the same time, the level of manifestation in this group of characters is highly dependent on environmental conditions. Table 2 presents an example of the typical influence of abiotic stresses on the development of length of the main root (3 week old plants-length of main root in cm). There is a possibility to conclude that among analysed cultivars difference in length of main roots (in standard conditions) was not obtained, but on the other hand, there is a measurable influence of stress conditions. (It is known, that among contemporary varieties there is a lower variability in ma-

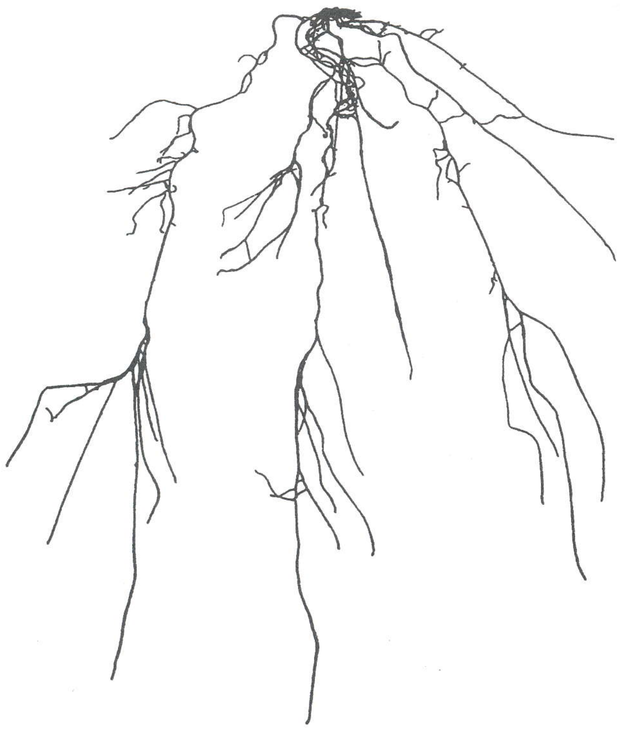

Fig. 1. Development of the root system of juvenile plants – seeds from standard conditions

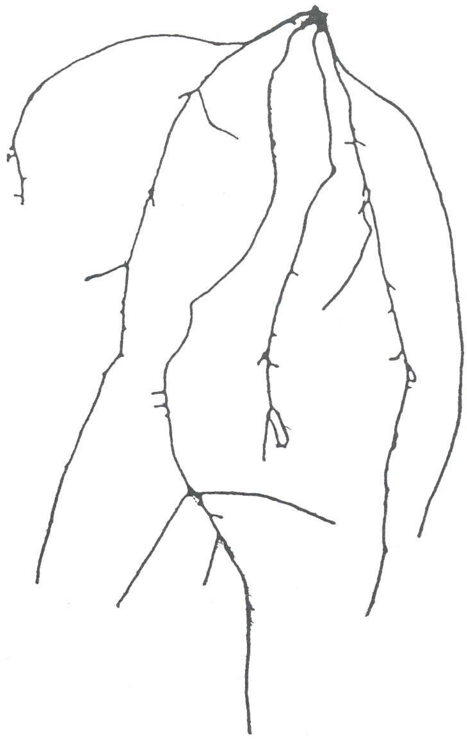

Fig. 2. Development of the root system of juvenile plants – seeds from low level of nutrients

jority of measured plant traits.Very similar development is in shoot traits and in root traits. Present work presented the results i.e. the length of main root is an example of this convergence. The consequence of this convergence is the increasing demand of cultivars with special traits including possibilities of using old cultivars as genetic sources of new average traits and as a source of new variability.)

The typical – basic types of the influence of different abiotic stresses on the morphology of the root system in the filial generation– i.e development of the roots from the seeds from standard and stress conditions are given in the pictures for three week old plants (Figs 1–5). Basic information about morphology of root system is in Table 3.

The obtained results were statistically significantly different ($P < 0.05$) in measured total length of root system. There is a possibility to conclude that the length of the root, i.e. very important trait in plant production depends on the genotype and especially on the environmental conditions (type of stress). Seed vigour and especially trait of roots of sprouting plants is one of the key issues for crop production. The improved response of cultivars to stress conditions is available via plant breeding.

DISCUSSION

Plant adaptation to the environment influences the expression of the full genetic potential for growth and reproduction. An understanding of the principles involved in plant adaptation to stress will enable optimisation of practices to improve agronomic production and minimise damage to environments. Studies on the effects of stresses on the quality of the seeds are very important for both agricultural and industrial processing. Many of the consequences of stress on seed production depend upon the stage of reproductive development when the stress is experienced.

Table 3. Root system in the filial generation-seeds from different provenance (standard conditions – 100%)

Conditions	Total length (cm)	Number of tips	Number of branches	Drought weight	Volume (cm^3)
1. Standard conditions	100	100	100	100	1.51
2. Low level of nutrients	95	89	90	95	1.49
3. Drought conditions	83	75	82	75	1.4
4. Drought conditions + low pH	59	50	55	50	1.35
5. Drought conditions + high temperature	60	55	58	45	1.35
6. Drought + low pH + high temperature	43	43	20	15	1.2

Fig. 3. Development of the root system of juvenile plants – seeds from drought conditions

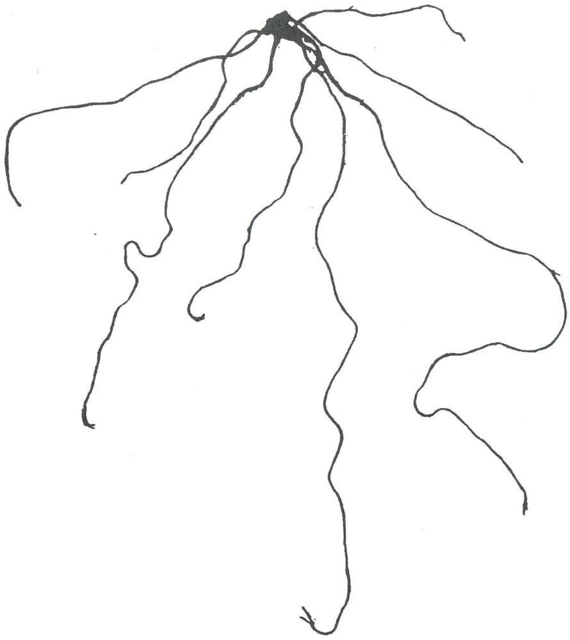

Fig. 4. Development of the root system of juvenile plants – seeds from drought and low pH conditions

Fig. 5. Development of the root system of juvenile plants-seeds from drought, low pH and high temperature

The future research will focus on the genotype x environment x cultural practices interactions upon seed production and seed quality and chemical composition with special interest in stress conditions such as water deficit, temperature stress, nitrogen stress etc. The consequences of stress are not only apparent during seed crop development. Seed crops grown under stress conditions may be difficult to harvest – inappropriate conditions for seed crop development can also increase the number of weed seeds which must be removed during cleaning process.

The quality of seeds is of great economic importance. It is necessary to identify effect of stress observed in different genotypes during seed production. The main aim of seed stress physiology is also necessary to identify the key genes or gene products which play a main role in controlling seed germination and stress physiological processing. Fundamental knowledge about genetically determined stress response is lacking. Many questions must be solved in relation to reaction of plants to stress. One of very essential problems in seed germination physiology is the understanding of molecular mechanisms controlling seed germination which will certainly lead to an understanding of seed dormancy and preharvest sprouting.

It has been shown that there are great cultivar differences in the influence of abiotic stresses especially of drought and high temperature on the different seed traits and technological quality and grain protein contents of the different cereal cultivars i.e. testing seeds from different localities and cultivar differences is desirable (Torres et al., 1982; Welch, 1977). From the agronomic point of view, the influence of individual abiotic stresses and their combinations has an impact on the seed traits, on the first phases of plant development and the following yield formation (Bláha et al., 1997, 1998). Drought, high temperature and other abiotic stresses have a large influence on the basic metabolic processes, yielding traits and traits of seed technological quality. It has been concluded that seed provenance – especially influence of different abiotic stresses had also a very important effect on the root system in the next generation after abiotic stresses. The improved response of cultivars to stress conditions is accessible via plant breeding. Seed vigour and especially trait of roots of sprouting plants that is some of the key issues for crop production. The cultivar differences in nutrient uptake and nutrient distribution of N, P, K, Ca, Mg and Na to the roots and especially shoots exist. The cereals with higher nutrient uptake and with higher distribution of nutrients to the shoot are more tolerant to the different abiotic stress

Table 4. Influence of abiotic stresses and their combinations on the content of net energy of grain and straw of winter wheat (kJ.g^{-1} of dry matter)

Straw						
Cultivar	S	LN	D	D + HT	D + pH	HT + D + pH
Astella	11.05	13.81	13.12	14.52	12.71	11.31
Estica	15.07	13.61	12.62	11.78	14.4	10.53
Ilona	12.71	10.48	11.55	10.93	10.72	11.61
Samanta	14.22	10.57	12.34	11.07	11.33	12.65
Olga	12.71	10.48	11.55	10.93	10.72	11.61
Plodna	12.91	11.74	10.54	10.41	11.87	10.04
Patria	13.68	12.70	13.77	14.47	13.49	11.88
Šárka	14.5	12.23	11.47	13.47	12.18	11.83
Grain						
Cultivar	S	LN	D	D + HT	D + pH	HT + D + pH
Astella	13.8	13.79	13.88	12.73	13.76	16.47
Estica	12.46	14.24	13.86	14.94	13.38	12.54
Ilona	14.46	11.52	12.43	13.72	12.21	11.45
Samanta	15.08	12.62	13.96	13.35	10.32	11.87
Olga	15.62	12.95	12.52	12.96	11.28	10.15
Plodna	16.53	12.53	13.08	13.66	10.52	11.85
Patria	11.06	11.99	11.86	10.69	10.36	11.82
Šárka	16.29	15.71	15.30	13.01	10.26	12.10

Abbreviation see Table 1

conditions (low change of root morphology). The degree of tolerance to the abiotic stress is now under the genetic control. Stress abiotic factors affect lot of seed traits and traits of sprouting plants-especially basic root traits: root length, root surface, root weight, nutrient uptake, number of root tips, number of root hair, number of lateral roots and root density.

It has been shown that the grains from stressed plants have a significantly lower germination power activity compared to unstressed plants. The vigour of seeds is not only result of weight and chemical composition of endosperm, but there is also a large influence of embryo vigour. Abiotic stress factors affect significantly embryo traits.

It was concluded that the content of rich in energy matters in straw and grains is influenced by effecting abiotic stresses, as with the stressed plants there was a decrease of net energy compared with control variant. In the presented example (Table 4) is comparison of standard and stress conditions. The statistically significant differences ($P < 0.05$) are especially at comparison of standard conditions and combination of the three abiotic stresses (HT + D + pH).

These relatively large changes are also determined by changes in anatomical construction of the caryopsis, where with the stressed grains the pericarp and seed coat layers are thicker and the cuticle is more suberized. There are also palpable anatomical changes in the embryonic part of caryopsis. Cultivar differences in analysed traits were obtained. There is a possibility to use the obtained results in plant breeding.

Considering the gathered results it can be stated that combination of abiotic stresses leads to a conclusive decrease of energy accumulation into the generative organ of wheat which results in worse germination of seed stock and decreased viability of plants. We can state accordingly with other authors (Golley, 1961; Hansen, Diepenbrock, 1994) that energise value of plant material is the function of genotype and it depends also on the surrounding conditions. Changes of energetic value of grain from the control plants and from stressed plants have been also given by their different chemical composition. Grains produced under stress conditions contained more proteins related to starch content and less carbohydrates compared with control grains. Changes in chemical composition influenced also the content of energy, as by Paine (1971), Hoffmann (1988), the amount of energy is limited by portion and mutual combination of individual matters, which form individual plant organs. On the basis of our results we suppose that combustion heat calorimetry could be one of the criteria for determination of agricultural crops tolerance to abiotic stresses (Hnilička et al., 2000).

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REFERENCES

BLÁHA, L. – HNILIČKA, F. – NOVÁK, V. – MANEV, M.: Influence of abiotic stresses on different seed traits, plant development and yield formation. In: ZIMA, M. – BARTOŠOVÁ L. (eds): Short Communications, Volume I, ESA, 5th Congr., Nitra, Slovakia, 28th June–2nd July 1998: 331–332.

BLÁHA, L. – NOVÁK, V. – ZÁMEČNÍK, J. – HNILIČKA, F. – FRANČÍKOVÁ, I.: Influence of abiotic stresses on seed germination, quality and seed production, In: COST 828, Workgroup 2, Meeting, Barcelona, Spain, November 10, 1997: 5.

GOLLEY, F. B.: Energy values of ecological materials. Ecology, *42*, 1961: 581–584.

HANSEN, F. – DIEPENBROCK, W.: Pflanzenbauliche Aspekte der Energie und Stickstoffbilanz des Rapsanbaus. Fett Wissenschaft Technol., *96*, 1994: 129–136.

HNILIČKA, F.: Vliv dusíkaté výživy na fyziologické charakteristiky a obsah energie u pšenice ozimé (Effect of nitrogen nutrition upon physiological characteristics and energy content in winter wheat plants). [Ph.D. Thesis.] Prague, Czech University of Agriculture 1999. 98 pp.

HNILIČKA, F. – NOVÁK, V.: Accumulation of energy to vegetative and generative parts of winter wheat plants. In: 8th Days of Plant Physiology (Book of Abstracts), Olomouc, 7. 7.–10. 7. 1998a: 96.

HNILIČKA, F. – NOVÁK, V.: Influence of different doses of nitrogen on contents of energy in stalks and leaves of winter wheat plants, In: Seed Science in the Field of Genetically Controlled Stress Physiology. COST 828 action. INRA, Toulouse centre, France, November 1998b: 11–14.

HNILIČKA, F. – BLÁHA, L. – ZÁMEČNÍK, J. – NOVÁK, V. – OTTOVÁ, M.: Využití kalorimetrie při studiu odolnosti rostlin vůči abiotickým stresům (Utilisation of calorimetry during studies of plant resistance to abiotic stresses). In: TARABA (ed.): Proc. Kalorimetrický seminář 2000, Zvíkovské podhradí, 29. 5.–1. 6. 2000: 71–74.

HOFFMANN, P.: Der thermochemische Energiegehalt der pflanzlichen Biomasse unter besonderer Berücksichtigung produktionsbiologischer Aspekte. Wiss. Z. Hochsch., Potsdam, *32*, 1988: 19–25.

PAINE, R. T.: The measurement and application of the calories to ecological problems. Ann. Rev. Ecol. Systematics, *2*, 1971: 145–164.

TORRES, J. L. – PAULSEN, G. M.: Increasing seed protein content enhances seedling emergence and vigour of seeds. J. Plant Nutr., *5*, 1982: 1233–1140.

WELCH, R. W.: Seedling vigour and grain yield of cereals grown from seeds of varying protein contents. J. Agric. Sci., *88*, 1977: 119–125.

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Vliv abiotických stresorů na výnos, vlastnosti semen a vlastnosti kořenů u pšenice ozimé (*Triticum aestivum* L.).

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V práci se hodnotily rozdíly v citlivosti odrůd ozimé pšenice Astella, Estica, Ilona, Patria, Plodna, Šárka k uvedeným vlivům prostředí: standardní hladina živin, nízká hladina živin, sucho, sucho a nízká hladina živin, sucho a vysoká teplota, sucho a vysoká teplota a nízké pH. Představují základní stresové podmínky, které se vyskytují v přírodních podmínkách České republiky.

Abiotické stresy měly významný vliv na výnosové prvky, vlastnosti kořenů, fyziologické znaky semen a v následné generaci na vlastnosti klíčních rostlin – zejména na morfologické vlastnosti kořenů (délka kořenů, počet bočních větví, počet kořenových pupenů). Statisticky významné rozdíly ($P < 0,05$) mezi sledovanými znaky u odrůd byly zjištěny pouze u sklizňového indexu, počtu klásků v klasu, hmotnosti tisíce zrn a u délky klasu. Jde o výsledek působení relativně silného vlivu abiotických stresů.

Patria, Olga a Samanta jsou odrůdy s nejlepší tolerancí k abiotickým stresům v hodnoceném souboru odrůd. Odrůdy Plodna a Estica se ukazují jako odrůdy s nejnižší tolerancí vůči abiotickým stresům. Z výsledků měření spalovací kalorimetrie vyplývá, že semena produkovaná v podmínkách abiotických stresů mají menší množství sušiny a nižší obsah energie na jednotku sušiny (= obsah energie v 1 g sušiny). Tento jev je obvykle spojen se změnou anatomie semen (zejména oplodí), s poklesem energie klíčení a se změnou růstu a vývoje rostlin.

Tolerance odrůd vůči abiotickým stresům je dědičně podmíněná odrůdová vlastnost. Ze získaných výsledků vyplývá možnost šlechtit na zvýšenou toleranci odrůd vůči abiotickým stresům, neboť fyzikální stres osiva hraje často velmi významnou roli v růstu a vývoji rostlin a prostřednictvím vlastností semen i v následné generaci.

abiotické stresy; vlastnosti semen; výnosové prvky; vývoj kořenů; kalorimetrie; odrůdové rozdíly

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