New and Unusual Report

Destruction of Chlorophyll in Emerging Seedlings of Spring Barley Associated with Environmental Stresses

Václav KŮDELA[1], Bohumila VOŽENÍLKOVÁ[2], Radka KREJZAROVÁ[1], Václav KREJZAR[1] and Michal JANOUCH[3]

[1]Department of Bacteriology, Division of Plant Medicine, Research Institute of Crop Production, Prague-Ruzyně, Czech Republic; [2]Faculty of Agriculture, University of South Bohemia, České Budějovice, Czech Republic; [3]Solar and Ozone Observatory, Czech Hydrometeorological Institute, Hradec Králové, Czech Republic

Abstract

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An unusual disorder occurred on spring barley seedlings in southern and central Bohemia in April 2005. Affected seedlings showed conspicuous bleached or straw-coloured areas on tips of the first leaves. There were very sharp, distinct, horizontal boundaries between the green basal and discolored tip parts of the leaves. It was remarkable that these boundaries were at the same position on all affected first leaves of seedlings from the same field. Affected seedlings were randomly distributed in the fields, and their incidence ranged from about 20 to 70% according to location. Based on meteorological data it can be concluded that the colour abnormality in emerging seedlings was associated with specific environmental stresses, being effective in certain chronological order on sensitive plant tissues during the period from 6 to 8 days after seeding. These stresses include frosty mornings followed by clear days with high solar radiation with a high UV Index.

Keywords: *Hordeum vulgare* L.; colour abnormality; environmental stresses; UV radiation; Czech Republic

In spring 2005, we obtained samples of spring barley seedlings in stage 1 of the Feekes growth scale with unusual disorder symptoms. The samples came from two fields in southern and central Bohemia (locations Roudné and Kněževes).

The affected barley seedlings showed conspicuous bleached or straw-coloured areas on the tips of the first leaves. There were very sharp, distinct, horizontal boundaries between the green basal and the discolored tip parts of the leave blades. It

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Figure 1. Bleached to straw-coloured areas on tips of the first leaves of spring barley seedlings. Symptoms at location Roudné (June 14, 2005). (Photo: V. Krejzar)

was remarkable that these horizontal boundaries were in the same position on all affected first leaves of seedlings originating from the same field (Figure 1). The bleached parts failed to recover. Field examination showed a random distribution pattern of affected seedlings. The incidence of affected plants was about 20% at the location Kněževes and 70% at Roudné.

The colour abnormality in emerging seedlings resembled vaguely a phenomenon called colour banding or rugby banding (rugby stocking) which occurs on the first and second leaves of some cereal crops as reported in USA, Canada, Europe and New South Wales, Australia (Vanterpool 1949; Wilcox 1959; Riesselman 1997; Wiese 1998; Murray 2003).

Different from the colour abnormality observed in the CR in 2005, the symptoms of colour banding reported in these countries include a series of one to four distinct, yellow white transverse bands on coleoptiles and leaves. The bands are up to 2 cm wide and alternate with bands of normal tissue (Riesselman 1997; Murray 2003). Because emergence is normally completed within 3 or 4 days, such plants have three or four bands but are otherwise normal (Riesselman 1997).

Various environmental stresses, being effective in a certain chronological order on sensitive tissues of plants, are considered to be the cause of colour banding. The disorder is mostly due to cold nights and sunny mornings in the early developmental phase of some cereal crops. Colour bands stop developing once the growing point has reached the level of the soil surface (Murray 2003). Colour banding sometimes also occurs when water held on frosted leaves is quickly dried by surface heat generated by solar radiation (Anonymus 1998). A disorder known as heat banding happens sometimes when temperature fluctuations at the soil surface are very extreme. It is not uncommon to record temperatures close to 50°C at the soil surface in some fields with poor plant cover. The types of heat injury produced on cereal seedlings between temperature limits of 42 and 52°C at the

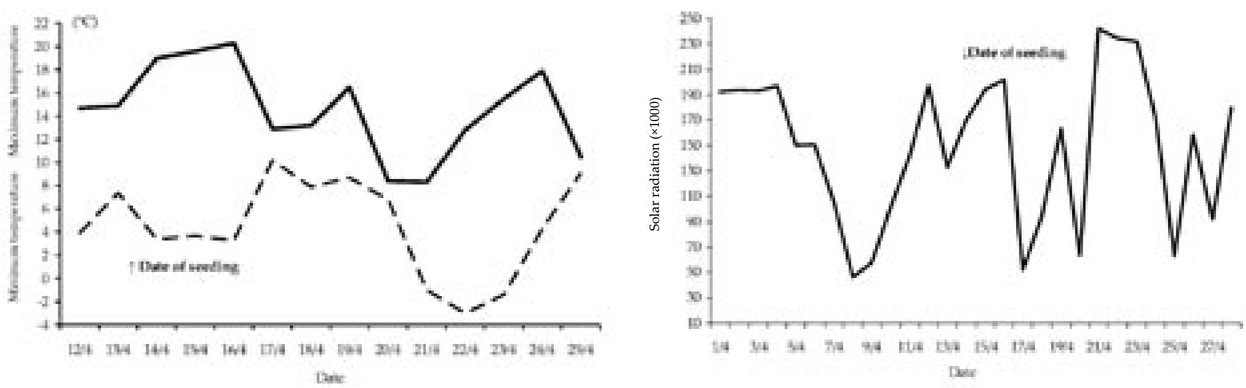

Figure 2. Timing of critical environmental factors – daily minimum and maximum temperatures and solar radiation – which were associated with colour abnormality in spring barley seedlings at location Roudné (Source: Hydrometeorological Institute, České Budějovice)

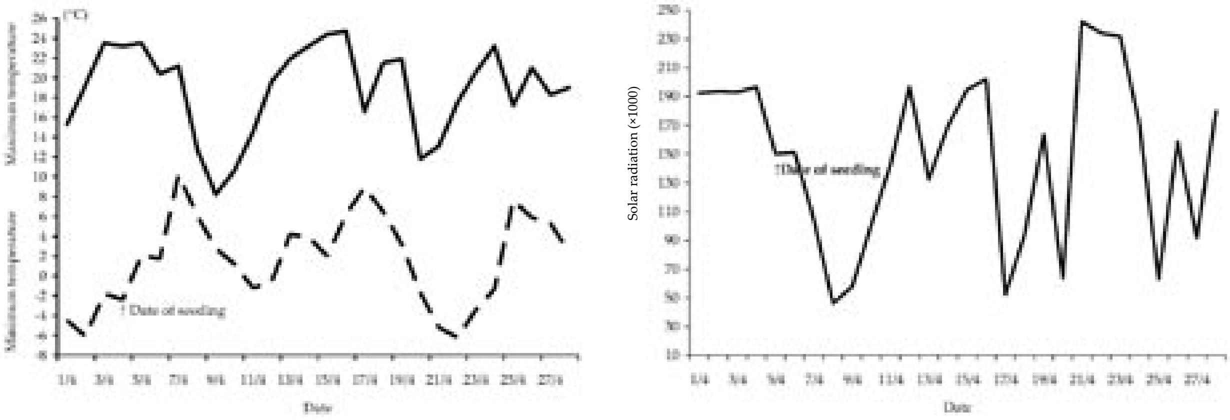

Figure 3. Timing of critical environmental factors – daily minimum and maximum temperatures and solar radiation – which were associated with colour abnormality in spring barley seedlings at location Kněževes u Prahy (Source: Meteorological Station of the Research Institute of Crop Production, Prague-Ruzyně)

soil surface are virtually indistinguishable from those produced by temperatures at or near the freezing point (Vanterpool 1949; Anonymus 2005).

Plants, in their need to capture sunlight for photosynthesis, are inevitably exposed to the damaging effects of UVB radiation. The highly energetic photons of these wavelengths cause damage to DNA and other macromolecules, which can lead to cellular injury, mutation or death (Bieza & Lois 2001). Chlorophyll may conceivably be destroyed by the UV of sunlight. However, under natural conditions, the chloroplasts are not likely to receive UV irradiation to produce these severe effects (Levitt 1972). A variety of adaptations have evolved that help plants to cope with exposure to UV. The UV-absorbing flavonoids and sinapates have been implicated in UV protection (Landry *et al.* 1995; Bieza & Lois 2001).

The symptoms of the colour abnormality on barley seedlings observed in the CR in 2005 do not entirely match those of the disorder known as colour banding. Thus, the aim of this paper was to determine which environmental factor(s) could have led to that colour abnormality.

MATERIAL AND METHODS

To determine whether environmental stress could have been be the cause of the colour abnormality on emerging cereal seedlings, the meteorological data (i.e. air temperature and solar radiation) from April 2005 from two locations in southern and central Bohemia (České Budějovice and Prague-Ruzyně) and situated near the fields with the occurrence of colour abnormality were analysed (Figures 2 and 3). The highest and lowest daily air temperatures were measured at 2 m above

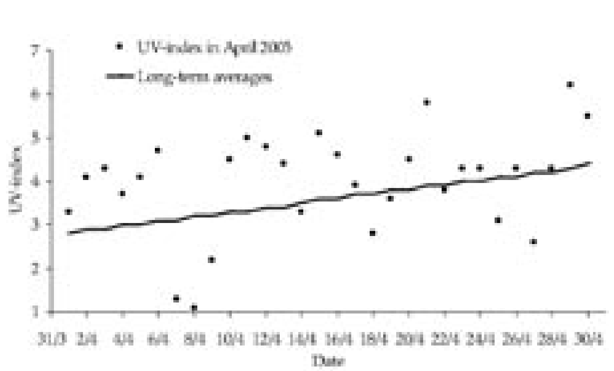

Figure 4. UV Index over the Czech Republic, April 2005 (Source: Solar and Ozone Observatory, Czech Hydrometeorological Institute, Hradec Králové)

Figure 5. Colour abnormality in spring barley leaves induced artificially by high temperature at the surface of the soil substrate (Photo: V. Krejzar)

soil level. In addition, we analysed the results of systematic daily measurements of UV radiation during April 2005 taken at the Solar and Ozone Observatory of the Czech Hydrometeorological Institute at Hradec Králové by means of a Brewer spectrophotometer B098 (Figure 4).

In a tentative laboratory test, we tried to simulate temperature fluctuations at the soil surface with the aim to trigger colour abnormality on emerging barley seedlings. The test was carried out in four variants, one control and three treated ones, with 12–15 seedlings in each variant. Seeds of spring barley cv. Akcent were sown in the soil substrate in pots to a depth of 1, 2 and 4 cm. Emerging seedlings in the coleoptile phase were exposed to a temperature of 2°C in the dark for 18 h. During this cold period the temperature of the soil substrate dropped from 29 to 2.5°C. The seedlings were then kept in a thermostat at 40°C for 3 h during which the temperature of soil substrate rose to 33°C. Immediately after removal from the thermostat, the temperature of the soil substrate was increased to 37, 38 or 40°C for 10 min using a hair dryer. The test was evaluated 3 d after the heat treatment.

RESULTS

An unusual colour abnormality on spring barley seedlings was observed in southern Bohemia (cv. Tolar, locality Roudné) and central Bohemia (cv. Prestige CPG, locality Kněževes u Prahy) in spring 2005 (Figure 1).

As it is known that colour banding on some emerging seedlings of small grains can be caused by stress from high or low temperature at the soil surface (Vanderpool 1949; Riesselman 1997), we analysed selected data of meteorological conditions during the 14 d after seeding at the two locations in question (Figures 2 and 3). This analysis indicated that the emerging barley seedlings might have been stressed and injured during the period from 6 to 8 days after seeding. In these days the minimum air temperature dropped below 0°C in the morning hours, the maximum air temperatures ranged from approximately 8 to 15°C (at locality Roudné) or 14 to 20°C (at locality Kněževes u Prahy) and there were clear days with high solar radiation, i.e. 231924 to 244281, or 142990 to 1962862 J/m^2 (Figures 2 and 3). It should be emphasised that the monthly sum of UV radiation over the Czech Republic in April 2005 was approximately 20% higher than the long-range normal. In the critical days, i.e. during the period from 6 to 8 days after seeding, the UV Index reached the value 5.0 (11.4) and 5.8 (21.4) (Figure 4).

In the laboratory test we tried to induce the colour abnormality on emerging barley seedlings. Colour abnormality similar to those observed in field conditions occurred when seedlings in the phase of coleoptile were exposed to 2°C for 18 h, then kept at 40°C for 3 h and immediately after that exposed to 38 or 40°C for 10 min (Figure 5). Depth of seeding had influence on the effect of high temperature at the surgace of the soil substrate. Hovewer, it is evident that such high temperatures at the soil surface did not occur in the two fields with symptoms of colour abnormality.

DISCUSSION

Considering the results of our analyses of meteorological data and laboratory tests, it can be concluded that the colour abnormality on emerging barley seedlings in the CR in 2005 was associated with specific environmental stresses, being effective in certain chronological order on sensitive plant tissues. These stresses include frosty mornings followed by clear days with high solar radiation connected with a high UV Index. With the exception of a high UV Index, all other environmental factors are those that are regarded as the cause of colour banding or rugby banding (Vanterpool 1949; Wilcox 1959; Riesselman 1997; Wiese 1998; Murray 2003).

To the best of our knowledge, the characteristic symptoms of colour banding or rugby stocking that occurred in many foreign countries, i.e. a series of one to four distinct, yellow white, transverse bands on coleoptiles and leaves of barley and other small grains, has so far not been recorded in the CR. The question arises whether the causative factors of colour banding occur rarely or not at all in this country. In Moravia, the eastern part of the Czech Republic, Benada *et al.* (1961) have given a detailed description of injury of emerging spring barley in form of a single bleached band on the first and second leaves. The part of the leaf above the band dropped down. They explained the symptoms by the tissue of emerging coleoptiles having been crushed by ice-encasement at the soil surface.

It is obvious that temperature extremes at the soil surface can bring about some abnormal effects or symptoms on cereal seedlings. This is probably due to the effects of temperature on the mechanism of chlorophyll formation (Vanterpool 1949). According to Murray (2003), pale transverse bands on coleoptiles and first or second leaves of small grains occur on emerging seedlings when bright, early morning sunlight destroys the chemical that is the precursor to chlorophyll faster than the plant can transform it into chlorophyll. When the seed is sown deeply, the coleoptile can often be very long. The first true leaf can then form inside the coleoptile and may need to push through to the soil surface. Leaves grow from a base and, in seedlings, the growing point remains below ground level for some time, particularly when seeds are sown deeply. The part of a leaf that emerges overnight remains white before daylight appears. On cold, bright, sunny mornings, the pro-chlorophyll in the newly-emerged part of the leaf can be destroyed by sunlight before it can be converted to chlorophyll. Therefore, these colour bands occur mostly if seeds are sown deeply and when there is clear weather in the days just after the seedlings begin to emerge. Clear and cold mornings occurring over several consecutive days thus cause a series of bands. The intensity of this banding is determined by the brightness of the early morning sunlight and the temperature. Colour bands stop developing once the growing point has reached the level of the soil surface.

The colour abnormality recorded in spring barley in the CR in 2005 can be regarded as a conspicuous disorder without or only minimal effect on the productivity of the crop. We found the same colour abnormality on seedlings of spring wheat this year but did not analyse it in detail. Only the first leaves were affected, so the crop was able to recover. The random distribution of affected plants in the observed stands is probably connected with their emergence coinciding exactly with the proper conditions.

Ultraviolet light can have detrimental effects on plants (particularly UVB) (Nielsen 1996). As far as we know, we have for the first time pointed out a possible association of UV radiation with the destruction of chlorophyll or its precursor in emerging seedlings of spring barley.

The UV region covers the wavelength range 100–400 nm and is divided into three bands: UVA (315–400 nm), UVB (280–315 nm) and UVC (100–280 nm). As sunlight passes through the atmosphere, all UVC and approximately 90% of UVB radiation is absorbed by ozone, water vapour, oxygen and carbon dioxide. UVA radiation is less affected by the atmosphere. Therefore, the UV radiation reaching the Earth's surface is largely composed of UVA, with a small proportion of UVB (Krzyscin *et al.* 2004; Schmalwieser *et al.* 2005).

Ozone levels vary over the year and even during a day. The monthly sum of UV radiation over the Czech Republic was approximately 20% above normal in April 2005. In critical days, i.e. in the period 6 to 8 d after seeding of barley, the UV Index reached the value 5.0 and 5.8, respectively. According to Levitt (1972), chloroplasts are not likely to receive enough UV irradiation to be damaged under natural conditions. However, stratospheric ozone affecting ground-level UV radiation exhibit both temporal and geographical variation. Therefore, it is possible that in future there may be a more frequent and higher incidence of damage of sensitive plants in the sensitive developmental phase by UV radiation than in the past in Central Europe. Indirect changes caused by UVB, e.g. changes in plant form, how nutrients are distributed within the plant, timing of developmental phases and secondary metabolism, may be equally, or sometimes more important than the damaging effects of UVB. It is to be hoped that an expected recovery of the ozone layer in the middle of the 21st century will stabilise the ground-level UV radiation at a harmless level.

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Abstrakt

Kůdela V., Voženílková B., Krejzarová R., Krejzar V., Janouch M. (2005): **Destrukce chlorofylu u vzcházejícího jarního ječmene spojená s povětrnostními stresy.** Plant Protect. Sci., **41**: 165–170.

V roce 2005 se v jižních a středních Čechách vyskytla v porostech jarního ječmene na vzcházejících rostlinách neobvyklá barevná abnormalita. Postižené vzcházející rostliny měly na vrcholech prvních listů výrazné vybělené anebo slámově žluté plochy. Bylo nápadné, že v rámci jednoho porostu byla vodorovná dělící hranice mezi zdravou a vybělenou částí čepele umístěna ve shodném místě u všech postižených rostlin. Příznakové rostliny byly náhodně rozmístěny po celém porostu. V závislosti na lokalitě bylo postiženo přibližně 20 až 70 % rostlin v porostu. Na základě meteorologických údajů lze usuzovat, že porucha zbarvení listů souvisela se specifickými povětrnostními stresy působícími v určité posloupnosti v citlivé vývojové fázi rostlin během šestého až osmého dne po zasetí. Těmito stresy byla mrazivá rána, po nichž následovaly jasné dny s vysokým slunečním zářením a velmi vysokým indexem UV-záření.

Klíčová slova: *Hordeum vulgare* L.; barevné abnormality; povětrnostní stresy; UV-záření; Česká republika

Corresponding author:

Prof. Ing. Václav Kůdela, DrSc., Výzkumný ústav rostlinné výroby, odbor rostlinolékařství, oddělení bakteriologie, 161 06 Praha 6-Ruzyně, Česká republika
tel.: + 420 233 024 427, fax: + 420 230 310 636, e-mail: kudela@vurv.cz