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Interactions of SO_2 and Drought Stress on *Picea abies*[1])

by

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With 2 Figures

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Summary

TESCHE M., FEILER S. & MICHAEL G. 1989. Interactions of SO_2 and drought stress on *Picea abies*. – Phyton (Austria) 29 (2): 291–297, with 2 figures. – English with German summary.

Actions of complex environmental stress on plants do not depend only on stress intensity and genotypic reactivity of plants to stress, but also on the constellation of stressors as well as the manner of their influence (continuous, intermitting, alternating). Exemplified by complex SO_2 and drought stress different responses of 3–4-year-old spruce seedlings (*Picea abies* [L.] KARST.) to simultaneous or subsequent influence of both stressors are described.

Based on the physiological parameters used for indication of stress (photosynthesis, peroxidase acitivities, electrical conductivity and proline content of needles) it was possible to make observations on synergistic, antagonistic and superimposing responses to the complex influence of both stressors. In certain stress constellations small stress intensities may cause an adaption stimulus on plants.

Zusammenfassung

TESCHE M., FEILER S. & MICHAEL G. 1989. Wechselwirkungen zwischen SO_2- und Trockenstreß bei *Picea abies*. – Phyton (Austria) 29 (2): 291–297, mit 2 Abbildungen. – Englisch mit deutscher Zusammenfassung.

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[1]) The paper was presented at the 6th Congress of the Federation of European Societies of Plant Physiology (FESPP) 1988 by M. TESCHE.

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Wirkungen von komplexem Umweltstreß auf Pflanzen sind nicht nur von der Streßintensität und dem genotypischen Reaktionsvermögen von Pflanzen gegenüber Streß, sondern auch von der Konstellation der Stressoren und der Art und Weise ihres Einwirkens (kontinuierlich, intermittierend, alternierend) abhängig. Am Beispiel von komplexem SO_2- und Trockenstreß werden unterschiedliche Reaktionen von 3- bis 4jährigen Fichtenjungpflanzen (*Picea abies* [L.] KARST.) auf gleichzeitiges oder aufeinanderfolgendes Einwirken der beiden Stressoren beschrieben.

Anhand der zur Streßindikation genutzten physiologischen Parameter (Photosynthese, Peroxydase, elektrische Leitfähigkeit und Prolingehalt der Nadeln) konnten synergistische, antagonistische und überdeckende Reaktionen auf das komplexe Einwirken der beiden Stressoren beobachtet werden. Schwache Streßintensitäten können bei bestimmten Streßkonstellationen einen Adaptionsreiz auf Pflanzen ausüben.

Introduction

Hitherto results of investigations on complex stress effects have been available only in relatively small numbers – in comparison with the great number of results on the effects of individual stressors (see SCHRADER, SCHÖNWALD & GREVE 1984; SCHRADER, SCHÖNWALD & DUJESIEFKEN 1985, 1986; SCHLEE & KÖCK 1987).

The reasons for this should be sought among other things in the difficulties encountered in experimentally simulating complex stress situations because to fulfill this task it is required to take into consideration endogenous as well as numerous exogenous factors which are not always simple to quantify or to be made reproducible for the layout (s. table 1). The endogenous, in most cases genetically fixed factors comprise among other things:

– resistance properties
– developmental states and
– regeneration behaviour

of the plants to be investigated.

Among the exogenous factors, in addition to the general experimental conditions (soil, temperature, moisture), stress intensity (stress magnitude×duration of stress), stress time (season or daytime of the action of stressors) and the combination of various stressors, stress constellation as well as kind and manner of the action of stressors should be regarded as well.

Thus, it is for instance possible that several stressors influence the plants simultaneously or successively, continuously with equalremaining intensity or – which always seems to be case under ecological conditions – intermittingly with alternating intensity (TESCHE & al. 1989).

This will be demonstrated only on the example in investigations of the effects of drought and SO_2 in different constellations under test field conditions on various physiological parameters of young spruces.

Table 1

Endogenous and exogenous factors which are of importance for stress research:

1. Stress factors

1.1. Single factors (stressor, e. g. SO_2 or frost, drought)
1.2. Complex of stressors and their constellation (e. g. SO_2+drought+frost)
1.3. Stress magnitude (e. g. concentration, temperature pressure, infection density)
1.4. Duration of stress (time duration of the action of stress magnitude)

2. System factors

2.1. Resistance properties of the biological system (e. g. seasonal frost resistance)
2.2. Developmental state of the biological system (e. g. ontogenetical or annual rhythm)
2.3. Persistance of stress impacts
2.4. Regeneration capacity of biological system

3. Experimental conditions

3.1. Stress time (season and period of daytime of the stress effect)
3.2. Site conditions
3.3. Methods for indicating stress impacts
- biochemically
- physiologically
- anatomically
- morphologically
- ecologically

Material and Methods

The general experimental conditions are shown in Table 2. The effects of both stressors (SO_2 and drought) were analyzed under the following constellations:
1. control=without both SO_2 and drought stress (c)
2. under drought stress (d)
3. under SO_2 stress (s)
4. under simultaneous SO_2+drought stress (d+s)
5. under primary drought and secondary SO_2 stress ($d \rightarrow s$)
6. under primary SO_2 and secondary drought stress ($s \rightarrow d$).

Under these conditions the majority of trial plants did not exhibit any ocularly visible or irreversible symptoms of injury.

Altogether the effects of the different stress constellations on 14 physiological parameters were investigated. From these the effects on
- photosynthesis,
- peroxidase activity,
- proline content and
- electrical conductivity in the diffusates of the youngest spruce needles will be demonstrated in the following.

Table 2

General experimental conditions:
Plant material: spruce (*Picea abies* [L.] KARST.) 3-5-year-old plants
Soil substrate: sandy loam, pH 5.6 (KCl), medium nutrient supply
SO_2-stress:
Stress magnitude: 0.8–1.0 mg·m^{-3} SO_2 (=0.31–0.38 ppm)
Duration of stress: 3–6 month, intermitting
Drought stress:
Stress magnitude: soil moisture content 7–12%; –0.55 to –0.22 MPa soil moisture potential (Ψ_{WS})
Duration of stress: 1–4 month, continously

Results and Discussion

Fig. 1 shows at first single effects of drought and SO_2 on the four test attributes.

It appears that under drought stress photosynthesis and peroxidase activities are reduced, while the prolin is drastically increased. In contrast to this SO_2 stress (with the applied stress intensity!) does not only lead to an

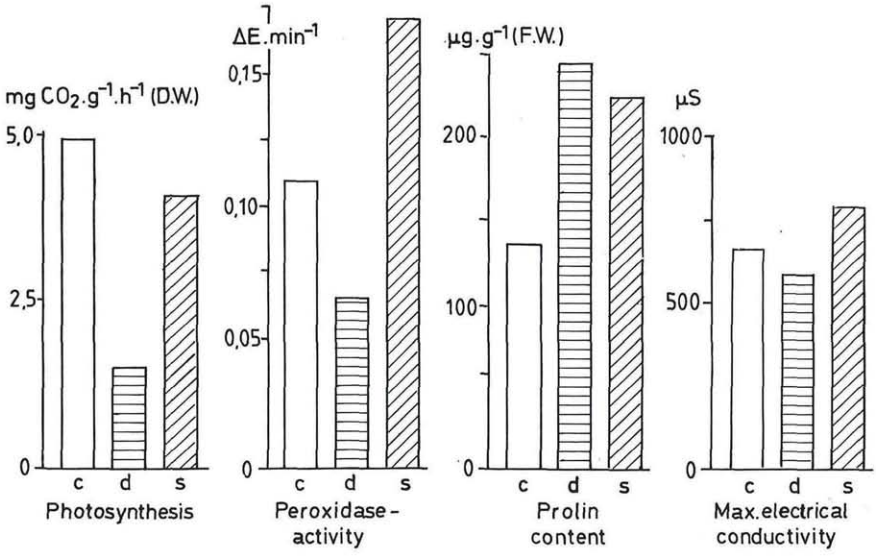

Fig. 1: Effects of drought or SO_2-stress
Blanc columns = control (c); horizontally hatched columns = under drought stress (d); obliquely hatched columns = under SO_2-stress (s)

increase of proline content, but also to a growing peroxidase activity and maximum electrical conductivity.

Only the photosynthesis shows – in consequence of SO_2 stress – a decrease, which, however, is not so strong as that caused by drought.

Fig. 2 shows the effects of the complex of stressors SO_2 and drought in different constellations.

It appears that the reactions of plants to a combinated SO_2- and drought stress are dependent on combination as well as on constellation of stressors.

In the case of a joint, simultaneous action of the two stressors (d+s) the physiological parameters show the following types of reactions:

1. Synergistic reaction:
Simultaneous SO_2 + drought stress leads to an additive change as compared with the effect to single stressors.
Example: increase of proline content

2. Antagonistic reaction:
Individually, the stressors cause a deviation from the same direction (increase or depression). Under simultaneous SO_2/–drought stress the tendency of deviation is maintained, but weakened.
Example: decrease of photosynthetic activity

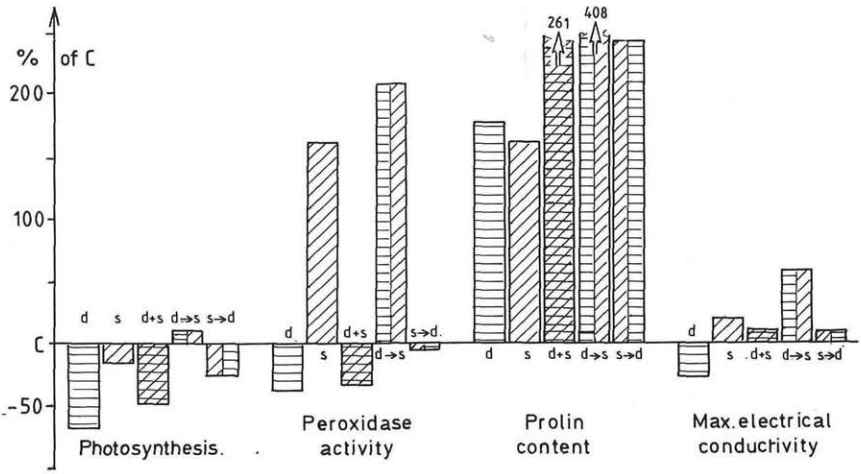

Fig. 2: Effects of drought and SO_2-stress in different constellations. Symbols see fig. 1.

d+s = under simultaneous drought + SO_2
d→s = under primary drought and secondary SO_2-stress
s→d = under primary SO_2 and secondary drought stress

3. Overlapping reaction:
Individually, the stressors cause a deviation in the opposite direction. Simultaneous SO_2 + drought stress overlaps the effects of single stressors approaching nearly a compensation. Due to this the effect of single stressors is not longer recognizable.
Example: peroxidase activity –
– decrease under drought stress
– increase under SO_2 stress
– compensation under simultaneous SO_2 + drought stress.

If a preceded primary drought stress is secondarily followed by an SO_2 stress (d → s), then only the proline content with synergistic reaction still indicates a complex action of both stressors.

Peroxidase activity and electrical conductivity are subjected to an increase, as it is the case under exclusive SO_2 stress (s. fig. 1). On the other hand, photosynthesis with slight increase instead of depression indicates adaptation to stress situation as a result of preceded drought stress.

Another picture will arise, if SO_2 as a primary stress precedes a secondary drought stress (s → d). Under these conditions only the synergistic reactions of the proline content will again indicate a complex stress situation.

Photosynthesis and peroxidase activities as well as values of electrical conductivity have approached the values of non-stressed control plants to such a degree that even in this case stress-induced adaption to further stress situations must be supposed.

A trial to summarize the results leads to the following conclusions:
1. Complex stress situations need not necessarily lead to a strengthening of the effect of single stressors.
2. Beside numerous endogenous and exogenous factors it also depends on stress constellations and intensity of single stressors how plants will respond.
3. Parameters suitable for stress indication may respond differently in various stress situations, stress combinations and stress constellations.
4. In certain stress constellations small stress intensities may cause an adaptation stimulus, a „roborierend" effect on plants (according to LARCHER 1987) and thus contribute to the maintenance of the functional ability and stabilization.
5. Stress situations, which require or favour the adaptation capacity of plants play an important constructive role as eustress in the development of resistance power against stress factors.

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