Effect of Different Weather Conditions on Selectivity of Post-Emergence Herbicides in Sugar Beet

VLIV POVĚTRNOSTNÍCH PODMÍNEK NA SELEKTIVITU POSTEMERGENTNÍHO HERBICIDNÍHO OŠETŘENÍ CUKROVKY

Kateřina Hamouzová, Miroslav Jursík, Petr Zábranský – Czech University of Life Sciences Prague

Weeds can grow very well in sugar beet stands and if they are not controlled, the yield can decrease dramatically (Zimdahl 2004). In the West and Central Europe, system of several post-emergence herbicide applications is currently used. For particular terms of application, herbicides and their rates are chosen according to weed spectrum and growth stages of both the weeds and the crop (Jursík et al. 2008). Most important active ingredients of herbicide in sugar beet are desmedipham and phenmedipham which are used for post-emergence control of annual broadleaf weeds. Desmedipham and phenmedipham inhibit photosystem II (PS II). The foliar absorption is fast, but the translocation in plant is small, with the move in the xylem (Abbaspoor and Streibig 2007). The mode of action is electron transfer blocking between the primary and secondary quinones (QA and QB) by binding to D1 protein of PS II in chloroplasts (Jursík et al. 2010). The electron transport is therefore negatively influenced, and simultaneously the production of ATP and carbon fixation is inhibited. The phytotoxic effect on sugar beet of these two active ingredients has been described by many authors (Mannerloef et al. 1997, Dale et al. 2006, Jursík et al. 2008). Selectivity of these herbicides are depended on environmental conditions and especially when application is used at high temperature and high intensity of solar radiation, growth of sugar beet is retarded (Mannerloef et al. 1997). Light regime seemed to be more important than temperature. It appears that also moisture stress change the herbicide penetration to plants. Possible reason is that with photosystem II inhibited, secondary reactions could be also reduces and thus the water stress might constitute a condition which triggers a protective mechanism (the slowdown of photosystem II activity) during which degradation of the herbicide could still proceed (Bethlenfalvay and Norris, 1977). Also, it was found that the response to herbicides is influenced by sugar beet variety (Wilson, 1998). The visual estimation of the symptoms as a measure of the response to herbicide is often too rough or is delayed. For the actual state of the plant physiology, the analysis of gas exchange or chlorophyll fluorescence parameters can be used, mainly for herbicides inhibiting PS II. PS II is the part of photosynthetic apparatus that is sensitive to environmental stress factors and some xenobiotics, which may lead to reduction of its activity (Ikeda et al., 2003).

The objectives of this study were:

1. Determine the effect of phenmedipham, desmedipham and their mixture with ethofumesate on some of fluorescence and photosynthesis parameters in sugar beet
2. Assess the potential of recovery of sugar beet after the treatment of herbicides

Material and Methods

Field conditions

A plot field trials were carried out in sugar beet (*Beta vulgaris* ssp. *vulgaris* var. *altissima*, variety Marietta) in Middle Bohemia (Prague), Central Europe (300 m above sea level), in 2011. Winter wheat was the previous crop. The seedbed was prepared by ploughing (depth 25 cm) at autumn and soil compactor (depth 5 cm) two days before sowing. Sugar beet was sown 28th March. The experimental plots were organised in randomised blocks with three replicates, with each plot size 21 m^2 (3 × 7 m). The row spacing was 0.45 m, with an in-row plant spacing of 0.16 m. The untreated control was had hand weeded throughout the growing season, similarly as not controlled weeds on other treatments.

Tab. I. Weather conditions and growth stages of sugar beet at tested application date

Description of treatment	Date and time of application	Weather					Growth stage of sugar beet
		Cloudness (%)	Temperature (°C)	Air Humidity (%)	Soil moisture	Wind speed (m.s^{-1})	
T1 unfavorable	21. 4. 14.00	0	21	33	dry	0	cotyledonary
T1 optimal	21. 4. 19.00	0	19	36	dry	0	cotyledonary
T2 unfavorable	2. 5. 12.00	30	15	45	dry	1	two or four true leaves
T2 optimal	2. 5. 17.00	100	9	85	wet	2	two or four true leaves
T3 unfavorable	18. 5. 13.00	20	23	38	dry	0	six true leaves
T3 optimal	18. 5. 19.00	30	22	33	dry	0	six true leaves

Application of herbicides

Three herbicides (Betanal Expert: phenmedipham 91 g.l^{-1}, desmedipham 71 g.l^{-1}, ethofumesate 112 g.l^{-1}); Destor: desmedipham 157 g.l^{-1}; Betasana SC: phenmedipham 160 g.l^{-1}) were tested. Herbicides were

Tab. II. Application rate of tested herbicides used in individual application time

Herbicide	Application time	Application rate of active ingredient ($g.ha^{-1}$)
desmedipham + phenmedipham + ethofumesate	T1	53 + 68 + 84
desmedipham + phenmedipham + ethofumesate	T2	71 + 91 + 112
desmedipham + phenmedipham + ethofumesate	T3	106 + 136 + 168
phenmedipham	T1	240
phenmedipham	T2	480
phenmedipham	T3	960
desmedipham	T1	314
desmedipham	T2	628
desmedipham	T3	942

applied in three times (T1, T2 and T3) and in two different application weather conditions – different part of day (Table I.). These application weather conditions are designated as "unfavorable" and "favorable". Application rates of tested herbicides increased in dependence on growth stage of sugar beet (Table II.). Herbicides were applied with a small-plot sprayer with Lurmark 015F80 nozzles delivering 200 $l.ha^{-1}$ spray volume at 0.25 MPa.

Measurement of phytotoxicity and yield

Seven days after each herbicide treatments, phytotoxicity was evaluated visually, assessing discolouration, necroses and growth inhibition as a percentage value compared to untreated plants. Yield of sugar beet was calculated (25th October 2011) from the two middle rows harvested in each plot.

Chlorophyll fluorescence measurement

Leaves of sugar beet were adapted in the dark at least 30 minutes prior measurement. The dark-adapted leaves were illuminated and fluorescence increases from the initial value (*F0*) to its maximum (*Fm*) within 1 second. At this stage, the primary electron acceptor is fully reduced and this allows to determine the maximum quantum efficiency of PS II photochemistry, defined as Fv/Fm, where $Fv = Fm – F0$. The calculation of the fluorescence parameter Fv/Fm was done according to Genty et al. (1989). In stressed leaves this ratio is lower than 0.8, while a proportion of the PS II reaction centre is inhibited. The chlorophyll fluorescence was measured with Imaging-PAM M-Series (Heinz Walz GmbH, Effeltrich, Germany) with help of ImagingWin ver. 2.32. Measurement was performed on 19th May 2011, 1 day after the last herbicide treatment (1 DAT). For the experiments requiring only determination of *FV/Fm*, measurements were obtained from application of a single saturating pulse to dark-adapted plants. Modulated beam was set to 1 Hz and light intensity of 0.5 $\mu mol.m^{-2}.s^{-1}$. Intensity of saturation pulse was 2700 $\mu mol.m^{-2}.s^{-1}$. We used variable chlorophyll fluorescence imaging to assess the effect of herbicides on the sugar beet variety Marietta. All measurements were performed on single leaf early morning under laboratory conditions (22 °C, 45 % RH).

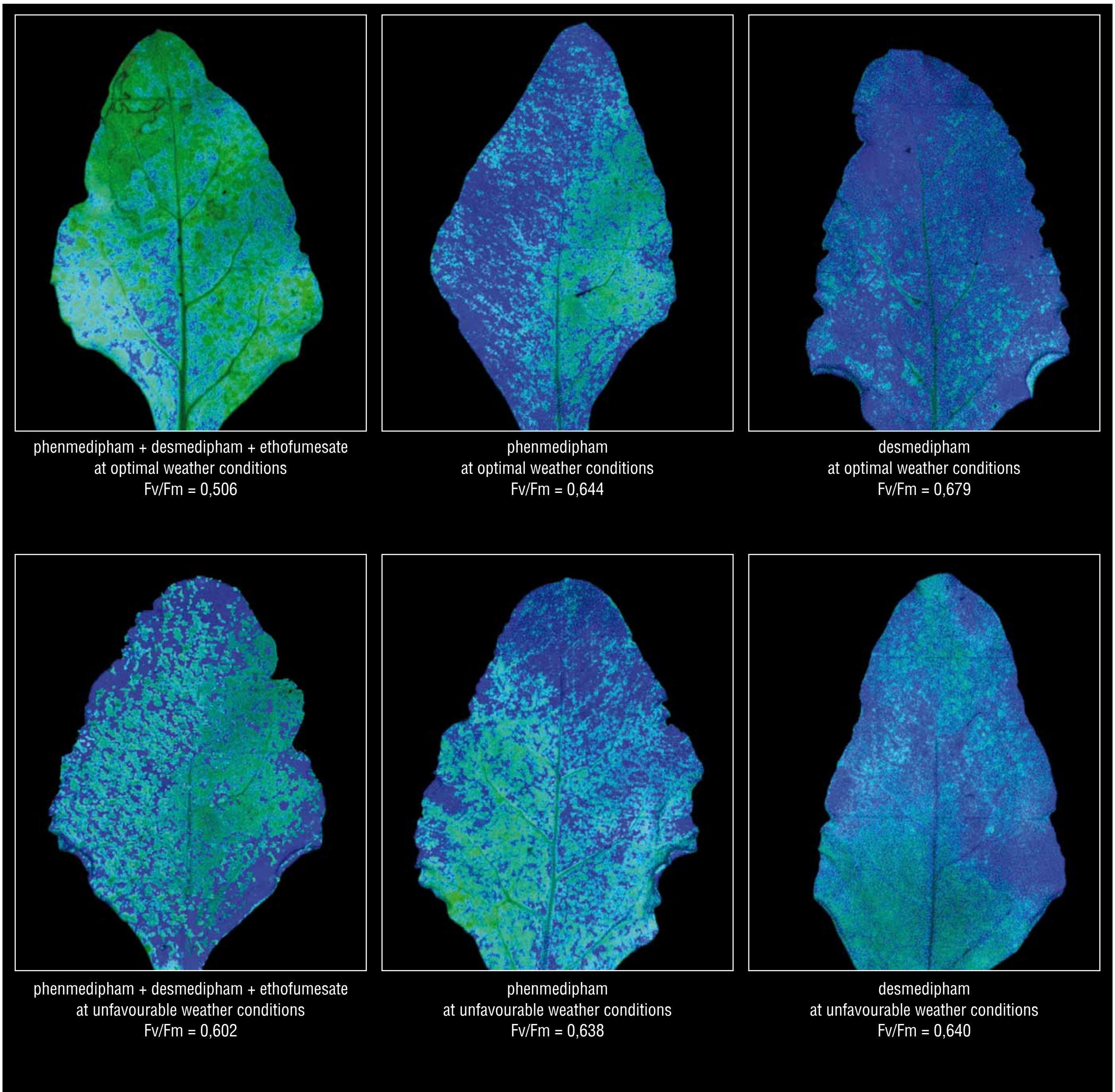
Gas exchange measurement

An infrared gas analyser CIRAS-2 (PP Systems) was used to measure the gaseous exchange of a leaf enclosed within the PLC 6 automatic universal leaf cuvette with LED light unit to control light intensity set to 1000 $\mu mol.m^{-2}.s^{-1}$. Photosynthesis rate ($\mu mol\ CO_2\ m^{-2}\ s^{-1}$) and transpiration rate ($mmol\ H_2O\ m^{-2}.s^{-1}$) were determined for each treatment. The measurement was conducted under field conditions on fully expanded leaves between 9–11 a.m.

Tab. III. Yield of sugar beet on tested treatments

Description of treatments	Yield of sugar beet roots	
	$t.ha^{-1}$	% rel.
hand weeded control	54,83 a	100
desmedipham + phenmedipham + ethofumesate at unfavorable conditions	49,10 a	90
desmedipham + phenmedipham + ethofumesate at optimal conditions	54,08 a	99
desmedipham at unfavorable conditions	44,02 a	80
desmedipham at optimal conditions	46,67 a	85
phenmedipham at unfavorable conditions	47,90 a	87
phenmedipham at optimal conditions	46,20 a	86
LSD (0.05) +/- Limits	16,37	
F-Ratio	0,56	
P-Value	0,7524	

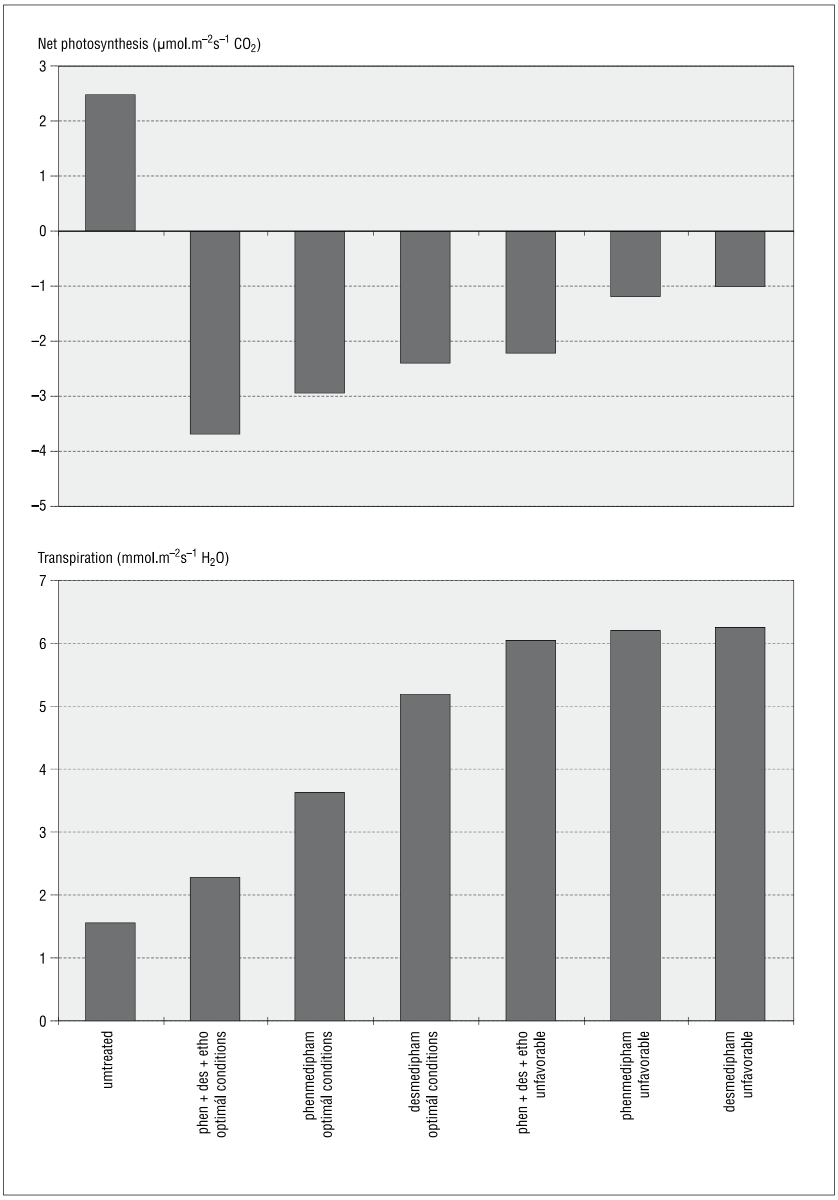
Fig. 1. Images for Fv/Fm parameter on sugar beet leaves one day after the exposure to herbicides



Results and Discussion

The fluorescence parameter *Fv/Fm* for control plants is close to 0.7. The exposure to herbicides had effect on chlorophyll fluorescence in sugar beet. Herbicide-affected plants exhibited signs of photosynthetic decline (Fig. 1). Plants experiencing desmedipham + phenmedipham + ethofumetase mixture displayed noticeably depressed *Fv/Fm* levels. *Fv/Fm* differed among treatments. Under the optimal spraying condition, mean *Fv/Fm* was 30 % lower compared to untreated check, while the value decreased to a lesser extent (15 %) when treated under unfavorable conditions. Injuries caused by phenmedipham alone caused 10 % decrease and statistically significant differences in relation to environmental conditions at spraying were not observed. *Fv/Fm* parameter showed that sugar beet was not affected by desmedipham injury as much as by phenmedipham, mainly under optimal spraying conditions. Nevertheless, the differences were not statistically significant. On the other hand, the influence of desmedipham on the transpiration and net photosynthesis was higher similarly to findings of Abbaspoor and Streibig (2007). They showed that desmedipham was more potent than the mixture and phenmedipham alone in sugar beet. The possible explanation for this observation is that higher temperatures and solar radiation intensities could increase injury caused by desmedipham (Bethlenfalvay et al., 1975). As presented in Bethlenfalvay and Norris (1977) the effect of exposure to high temperatures or to longer periods of sunshine is more pronounced in younger plants as well as the interaction between light regime and time of day at application. Morning application of herbicide resulted in greater sugar beet stand loss than afternoon whenever the maximum temperature on the day of spraying exceeded 22 °C (Winter and Wiese, 1978). The *Fv/Fm* test provides a level of accuracy not possible through visual evaluation alone. The *Fv/Fm* declines rapidly shortly after the herbicide treatment and can serve as an indicator of the herbicide injury. However, *Fv/Fm* may not be the most sensitive parameter for detection of fluorescence changes in herbicides with other modes of action than that of PSII inhibition. The observed herbicide effect on the fluorescence parameter was relatively weak, suggesting that PSII reaction centres are not severely damaged by the applied herbicides. Plants of sugar beet were not visually damaged (assessed 7 and 14 day after each application) by herbicides and differences in root yield among tested treatments were not significant (Table III.).

Fig. 2. The values of net photosynthesis and transpiration as a response of sugar beet to treatment of herbicide under optimal and unfavourable weather conditions



Photosynthesis was significantly reduced first day after treatment with phenmedipham + desmedipham + ethofumesate (Fig. 2) when treated under the optimal spraying conditions. Similarly to Prodoehl (1992), who showed that 1 DAT the reduction of photosynthesis was at about 50 % when treated with phenmedipham + desmedipham + ethofumesate respectively, but plants recovered substantially 10 DAT to 75 and 85 % of the untreated plots, later the yield losses associated with treatment were not significant. The magnitude of net photosynthesis rate decrease was lower when treated with one active ingredient solely.

In the study of Dixon et al. (1995) the treatment with phenmedipham increased the ratio of transpiration of sugar beet within 2 days of spraying. Similar findings were gained in this study, transpiration rates were increased after the spraying of all herbicides. The effect of the environmental conditions at the time of spraying was evident. Under the optimal environmental conditions, the sugar beet plants were more affected by herbicide than by the treatment in unfavourable conditions.

In conclusion, the gas exchange measurement seems to be more sensitive than chlorophyll fluorescence measurement for comparison of the susceptibility/selectivity of sugar beet to herbicides inhibiting PS II.

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Abstract

The basis for selectivity of phenmedipham, desmedipham and ethofumesate, incl. their mixtures, on sugar beet was studied under field conditions. The effect of many herbicides on sugar beet is affected by weather; therefore the sensitivity of sugar beet after herbicide application was studied to determine the effect of environmental conditions on the chemicals selectivity. The effects of herbicides on the rates of CO_2 uptake and transpiration, as well as chlorophyll fluorescence (*Fv/Fm*) of intact plants were measured.

Under the optimal spraying conditions, mean *Fv/Fm* in sugar beet treated with phenmedipham + desmedipham + ethofumesate was 30 % lower compared to untreated check variant, while the value decreased to a lesser extent (15 %) when treated under unfavorable conditions. Treatments with phenmedipham alone caused 10 % decrease and statistically significant differences in relation to environmental conditions at spraying were not observed. *Fv/Fm* parameter showed that sugar beet was not affected by desmedipham injury as much as by phenmedipham.

Photosynthesis was significantly reduced first day after treatment with phenmedipham + desmedipham + ethofumesate when treated under the optimal spraying conditions. The magnitude of net photosynthesis rate decrease was lower when treated with one active ingredient solely.

Under the optimal environmental conditions, the sugar beet plants were more affected by herbicides than by the treatment in unfavourable conditions shortly after the herbicide treatment. Later, sugar beet plants recovered substantially.

Key words: *Beta vulgaris*, chlorophyll fluorescence, transpiration, desmedipham, phenmedipham, ethofumesate.

Contact address:

Ing. Kateřina Hamouzová, Ph. D., Česká zemědělská univerzita, Fakulta agrobiologie, potravinových a přírodních zdrojů, Kamýcká 129, 165 21 Praha 6 Suchdol, Czech Republic, e-mail: jursik@af.czu.cz