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ASSESSMENT OF EFFICACY OF DIFFERENT HERBICIDE DOSES ON THE FAT HEN (*Chenopodium album*) USING CHLOROPHYLL FLUORESCENCE*

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A b s t r a c t. The obtained results indicate that under field conditions, the PS1-Meter apparatus can be used when estimating the efficiency of decreasing doses of herbicides CALLISTO 480 SC + ATPLUS 463 (surfactant) and BASAGRAN SUPER on fat hen (*Chenopodium album*) in stands of grain maize. It can be concluded that, as far as the efficiency of herbicides mentioned above is concerned, their doses can be reduced to 50 % of registered ones without any negative effect on the grain yield.

K e y w o r d s: grain maize; PS1-Meter; chlorophyll fluorescence; herbicides

INTRODUCTION

At present, growing grain maize becomes more and more important in the Czech Republic. This fact is documented by an increase of its acreage from 47 thousand hectares in the year 2000 to 84 thousands ha in 2006. Due to an increasing percentage of this crop in the crop rotation the pressure of harmful factors, which are characteristic for this crop, is also more and more intensive. Of weeds,

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barnyard grass (*Echinochloa crus-galli*), redroot pigweed (*Amaranthus retroflexus*), lambsquater (*Chenopodium album*) are the most frequent species. In combination with some other noxious factors, these (and a number of other weeds) can show a very negative effect on the yield and quality of harvested maize grain. For that reason both growers and researchers strive to reduce as much as possible the effects of these harmful factors and to create possibly most optimal conditions for growth and development as well as subsequent yield formation of cultural plants.

The application of herbicides is one of the most common possibilities of reducing the occurrence of weeds in stands of cultural crops. However, if used in a wrong way, these chemicals show negative environmental effects (i.e. water, soil and atmosphere pollution). For that reason it is necessary to apply herbicides in an efficient manner so that their negative effects would be reduced as much as possible but without any reduction of their killing effects on weed plants.

For the evaluation of the efficacy of herbicides various assessment scales can be used, however, their major disadvantage is that they are based on subjective estimates and for that reason the obtained results are largely dependent on opinions and experiences of persons evaluating results of individual experiments. For that reason it is usually very difficult to compare results of the same experiment established in different localities and evaluated by different experimenters. Because of the aforementioned reasons (and also due to the laboriousness and subjectivity of methods used until now) it would be very useful to evaluate the efficacy of herbicides on the basis of a method enabling an exact measurement of chlorophyll fluorescence. In the Netherlands (Plant Research International in Wageningen) the method of measurement of photosynthesis efficiency is used as a basis for the application of low doses of herbicides. The so-called Minimum Lethal Herbicide Dose (MLHD) method enables to calculate those minimum doses of herbicides belonging to the group of photosynthesis which enable the control of the occurrence of weeds on a given area and/or experimental plot (Haage *et al.* 2002). Kempenaar *et al.* (2002) studied and evaluated the efficacy of photosynthesis inhibition herbicides on the basis of measurements of chlorophyll fluorescence. Vondra *et al.* (2005, 2006, and 2007) and Smutný *et al.* (2006) described possibilities of application of reduced doses of herbicides in maize stands. The method of chlorophyll fluorescence measurements is now used also for detection of resistant weeds (Chodová *et al.* 1995, Norsworthy *et al.* 1998), estimation of the degree of seed maturity (Jalink *et al.* 1998), and evaluation of quality of stored fruit and vegetables (Toivonen and DeEll 1998). The application of methods based on chlorophyll fluorescence measurements usually results in lower operational costs as well as in reduced environmental load by herbicides (Klem 2006).

MATERIALS AND METHODS

Small plot experiments were established in the years 2005 and 2006 in the Field Experimental Station of the Mendel University of Agriculture and Forestry, Brno, situated in the area of the University Training Farm Žabčice. This locality (179 m above sea level, 49°01′ N, 16°37′ E) is situated 25 km southwards from Brno (South Moravia region, Czech Republic) in the maize-growing region, subregion K_2. This is one of the warmest regions in the Czech Republic with average annual temperature and precipitation sum of 9.2°C and 480 mm, respectively. July and January are the warmest and the coldest months, with average daily air temperatures of 19.3°C and –2.0°C, respectively. This is a dry region and the 30-year average of annual sums of precipitation is 480 mm. This region is also partly influenced by a precipitation shadow. Within the growing season, rainfalls are distributed very unevenly. June and March are the months with the highest and the lowest precipitation (68.6 mm and 23.9 mm, respectively). The annual sum of solar irradiation ranges from 1.800 to 2.000 hours.

According to the taxonomic system of soils of the Czech Republic, the soil in the Field Experimental Station in Žabčice is classified as gleic fluvisol which has developed on alluvial sediments of the Svratka River. These soils are without any marked diagnostic horizons and the parent substrate consisting of alluvial material is situated below a thin humus horizon. More marked symptoms of gley processes can be observed at the depth of below 0.60 m. In the course of the year, the groundwater level fluctuates between 0.80 m and 2.5 m. As far as the soil texture is concerned, the soil is classified as heavy to very heavy.

In individual experimental variants different doses of herbicides CALLISTO 480 SC + ATPLUS 463 (surfactant) and BASAGRAN SUPER were used (Tab. 1).

The experiment involved 7 variants with four replications. The size of plots was 21 m^2 (3 x 7 m).

Table 1. Experimental variants

Variant	Herbicide used	Dose (l ha^{-1})
1	CONTROL	–
2	CALLISTO 480 SC + ATPLUS 463	0.25 + (0.5%)
3	CALLISTO 480 SC + ATPLUS 463	0.1875 + (0.5%)
4	CALLISTO 480 SC + ATPLUS 463	0.125 + (0.5%)
5	BASAGRAN SUPER	2.0
6	BASAGRAN SUPER	1.5
7	BASAGRAN SUPER	1.0

Characteristics of the herbicides:

CALLISTO 480 SC is a systemic herbicide with the active ingredient mesotrione (480 g) which belongs to the group of triketons. CALLISTO 480 SC herbicide is applied for pre- and post-emergence control of annual dicot and monocot (grass) weeds infesting maize crops. The effective substance can be uptaken by both leaves and roots and it spreads within the plant in both acropetal and basipetal directions. In affected plants, it causes whitening (chlorosis) of leaves and necroses of tissues. Symptoms are visible as soon as 3 to 7 days after the application.

BASAGRAN SUPER is a contact postemergent herbicide with the effective substance bentazone (480 g) which belongs to the group of photosynthesis inhibitors. It is uptaken mainly through leaves but partly also through roots. The uptake through leaves is usually crucial and the killing effect is quicker. For good efficacy it is important that the leaf area of plants must be sufficiently developed so that the applied herbicide can be well absorbed. The symptoms involve whitening (chlorosis) and reduced photosynthesis, namely due to damage of cell membranes and disturbance in electron transport and specific CO_2 reactions.

In both years under study the same forecrop (i.e. winter wheat) was used in all experimental variants. The experiment was established in a conventional manner using the common technologies, i.e. medium-depth ploughing in the autumn and smoothing with harrows and land levellers in the spring. Prior to sowing the plots were dressed with urea at the dose of 120 kg N.ha^{-1}. No fungicides and insecticides were applied.

The seeds of hybrid grain maize Ribera were sown on 10th May 2005 and 28th April 2006 with a precise four-row drill Kleine Multicorn adjusted to interrow distance of 0.75 m and sowing depth of 0.06 m. The sowing density was 80 thousands seeds per hectare.

In the stage of the fourth true leaf, both herbicides were applied with the knapsack sprayer SOLO 432 on 6th June 2005 and 6th June 2006. The application pressure and the dose of water were 0.3 MPa and 300 l ha^{-1}, respectively.

The efficacy of herbicides was measured with the PS1–Meter apparatus. This portable equipment was developed in Wageningen and it is distributed by the company Agrifirm (The Netherlands). This instrument can measure the percentage of damage of the photosynthetic apparatus. Its scale has a range of values from 0 to 100 and low values indicate healthy plants while the high ones - damaged plants (Tab. 2). During the measurements the leaf was fixed in a ”clip“ (measurements were performed in darkness). Measurements were carried out using the youngest measurable leaf.

Table 2. Categorisation of photosynthetic apparatus damage (MLHD PS1 2004)

PS1-value	Predicted effect on plant
0-15	No effect
15-30	Small effect (temporary reduction of photosynthesis by about 20%)
30-50	Moderate effect (temporary reduction of photosynthesis by about 40%)
>50	Large effect (temporary reduction of photosynthesis by > 40%)

The degree of damage of the photosynthetic apparatus was measured with the PS1-Meter on the second, third, fourth, fifth and eighth day after the herbicide application.

Individual variants were harvested with the combine harvester SAMPO 2010 on 19th October 2005 and 20th October 2006. In all four replications two middle rows were harvested in each experimental variant. Harvested samples were weighed and their mass was converted to yield at 15% moisture content.

The obtained results were processed using the method of analysis of variance (ANOVA) and the significance of mean values was subsequently tested by means of Tukey's test using the statistical software UNISTAT 5.1.

RESULTS AND DISCUSSION

Results of ANOVA of two-year data indicated that the date of measurements, the dose of herbicides and their interaction showed a highly significant effect on PS1 values. The effect of the year on PS1 values was statistically insignificant. Subsequent testing (Tukey's test, P = 0.95) revealed statistically significant differences between the control and variants treated with different doses of herbicides CALLISTO 480 SC + ATPLUS 463 and BASAGRAN SUPER. In the case of the BASAGRAN SUPER herbicide there were no statistically significant differences in PS1 values measured after the application of individual doses.

In the case of the CALLISTO 480 SC herbicide applied with the wetting agent ATPLUS 463 a statistically significant difference in measured PS1 values was obtained only between the half and the registered dose and between the registered and the three-quarter dose.

In the course of individual measurements there were obvious differences in the promptness of action of applied herbicides. The effect of the systemic herbicide CALLISTO 480 SC applied with the ATPLUS 463 was a little slower (Fig. 1, 2). This was due to the fact that its effective substance was absorbed through both roots and leaves and thereafter was gradually distributed into other plant tissues. On the other hand, the contact herbicide BASAGRAN SUPER (Fig. 3, 4) caused a quick necrosis of sprayed plant tissues.

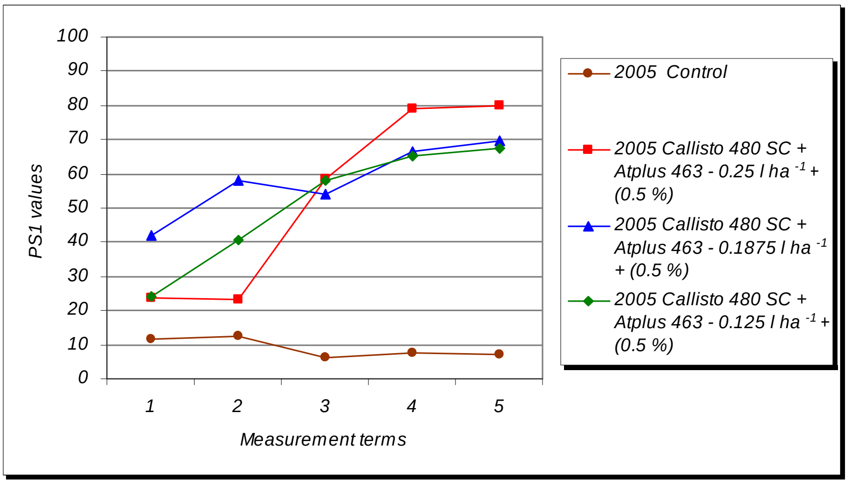

Fig. 1. The course of average PS1 values measured on individual dates in control and in variants treated with decreasing doses of herbicide CALLISTO 480 SC + ATPLUS 463 (year 2005)

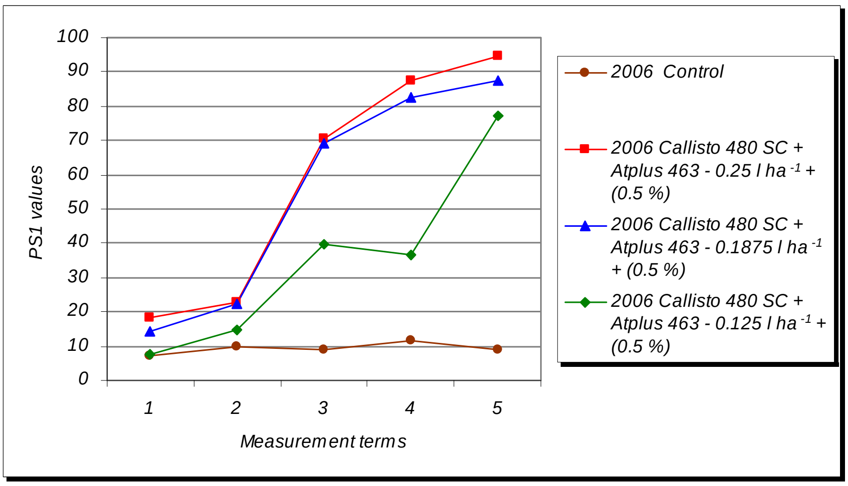

Fig. 2. The course of average PS1 values measured on individual dates in control and in variants treated with decreasing doses of herbicide CALLISTO 480 SC + ATPLUS 463 (year 2006)

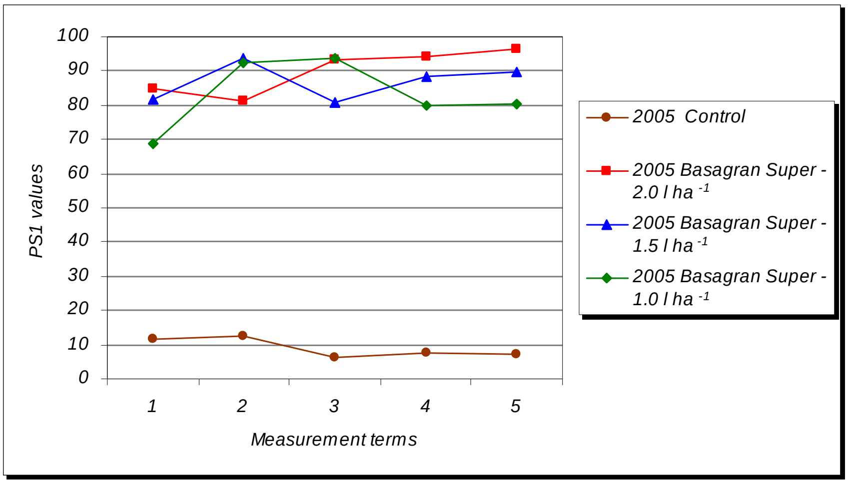

Fig. 3. The course of average PS1 values measured on individual dates in control and in variants treated with decreasing doses of herbicide BASAGRAN SUPER (year 2005)

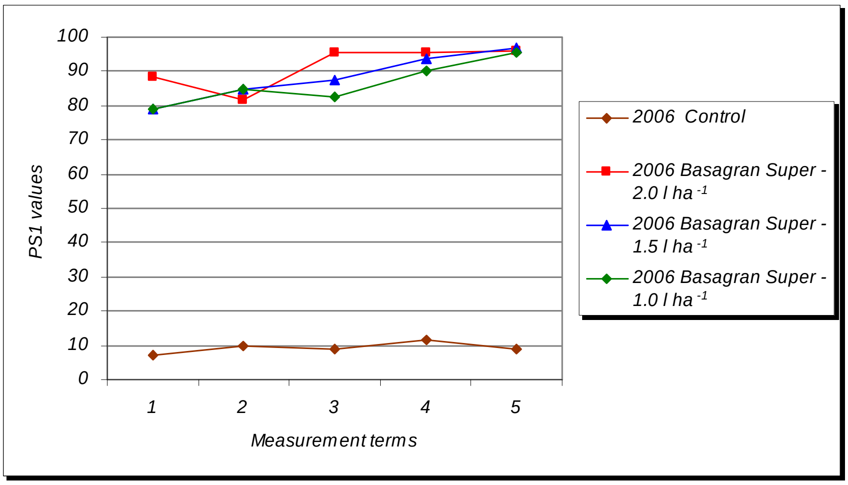

Fig. 4. The course of average PS1 values measured on individual dates in control and in variants treated with decreasing doses of herbicide BASAGRAN SUPER (year 2006)

In 2005, the average PS1 values ranged from 6.4 to 12.6. The highest and the lowest PS1 values were found on the second and the third date of measurements, respectively. In that year, the limit PS1 value of 15 (when the photosynthesis inhibition begins) was not overstepped.

In 2006, the average PS1 values ranged from 7.0 to 11.4; the lowest value (i.e. 7.0) was measured on the first date while the highest one (i.e. 11.4) on the fourth date of measurements.

After the application of increasing doses of the systemic herbicide CALLISTO 480 SC + ATPLUS 463 a gradual increase in PS1 values was recorded in both experimental years. This increase was caused by the effective substance mesotrione which showed a systemic (and therefore slow) action. Already on the second date of measurement (i.e. on the third day) the limit PS1 value of 15 was overstepped after the application of all tested doses of CALLISTO 480 SC + ATPLUS 463.

In 2005, variants treated with the registered dose of CALLISTO 480 SC + ATPLUS 463 (0.25 l ha^{-1} + 0.5%) showed average PS1 value of 23.8 already on the first date of measurements. On the second date, however, the average PS1 value decreased to 23.0, but thereafter the values increased to as much as 80.0. Similar efficacy was found in variants treated with a three-quarter dose of CALLISTO 480 SC + ATPLUS 463 (i.e. 0.1875 l ha^{-1} + 0.5%) to the registered dose. On the first and the second date of measurements the average PS1 values were 42.0 and 58.2, respectively. Thereafter they decreased to 54.0, but on subsequent dates they again began to rise and on the last (fifth) date of measurement the average PS1 value was 69.6. After the application of the lowest dose of CALLISTO 480 SC + ATPLUS 463 (i.e. 0.125 l ha^{-1} + 0.5%) a gradual increase in average PS1 values from 24.0 (on the first date of measurements) to as much as 67.4 (on the fifth date) was recorded.

In 2006, variants treated with the registered dose of CALLISTO 480 SC + ATPLUS 463 (0.25 l ha^{-1} + 0.5%) showed a gradual increase in PS1 values from 18.4 (the first date of measurements) to as much as 94.6 (the fifth date). As compared with the registered dose a similar response was observed also after the application of the three-quarter dose (0.1875 l ha^{-1} + 0.5%) when the measured PS1 values gradually increased as follows: 14.4 → 22.2 → 69.4 → 82.4 → 87.4). After the application of the lowest dose of CALLISTO 480 SC + ATPLUS 463 (0.125 l ha^{-1} + 0.5%), the PS1 values decreased from 39.6 to 36.6, but on the last (fifth) date they were as much as 77.4.After the application of the herbicide CALLISTO 480 SC + ATPLUS 463 its efficacy was sufficient and reliably killed all lambsquater (*Chenopodium album*) plants.

In variants treated with decreasing doses of the contact herbicide BASAGRAN SUPER high average PS1 values were recorded already on the first dates of measurements. This was due to the fact that its effective substance, bentazone, caused quick necroses on treated leaves.

In 2005, the application of the registered dose of BASAGRAN SUPER (i.e. 2.0 l ha^{-1}) caused a decrease in PS1 values from 85.0 (on the first date of measurements) to 81.4 (on the second). Thereafter the PS1 values evenly increased up to the value of 96.4. In variants treated with BASAGRAN SUPER at the dose of 1.5 l ha^{-1}, the highest PS1 values were recorded on the second date of measurements (93.6); thereafter they decreased to 80.6 and afterwards increased again to 88.6 and 89.6. As compared with the registered dose of BASAGRAN SUPER (i.e. 1.0 l ha^{-1}), in the variant treated with a half-dose of this herbicide the PS1 values gradually increased till the third date of measurements (93.6) and thereafter they decreased to 80.2 on the last (i.e. fifth) date of measurements.

In 2006, already on the first date of measurements the average PS1 value of 88.2 was obtained after the application of the registered dose of BASAGRAN SUPER (i.e. 2.0 l ha^{-1}). Thereafter there was a decrease to 81.8, followed by alternating increase and decrease from 95.6 to 95.4 and to final 96.0. In variants treated with a three-quarter dose of this herbicide a gradual increase in PS1 values from 79.2 (the first date of measurements) to 97.0 (on the last date) was recorded in 2006. After the application of the half dose of BASAGRAN SUPER (1.0 l.ha^{-1}), the changes in measured average values were as follows: on the first date the average PS1 value was 79.2, thereafter it increased to 85.0 on the second, and again decreased to 82.8 on the third date of measurements. On the fourth and the fifth dates the average PS1 values increased to 90.4 and 95.4, respectively. Also after the application of all the doses of BASAGRAN SUPER the efficacy of this herbicide was sufficient and all treated lambsquater plants (*Chenopodium album*) were quickly killed.

When evaluating yields of grain (converted to 15% moisture content) by means of analysis of variance the effect of year on yields was statistically highly significant. On the other hand, however, there were no significant differences in yields among individual variants of reduced doses of this herbicide.

In 2006 and 2005, the average (pooled) yields in all variants were 14.95 t ha^{-1} and 13.52 t ha^{-1}, respectively. Average grain yield (converted to 15% moisture content) obtained in both years in individual experimental variants is presented in Table 3.

In 2005, the highest average grain yield of 14.38 t ha^{-1} was obtained in the variant treated with the registered dose of herbicide CALLISTO 480 SC + ATPLUS 463 (0.25 l ha^{-1} + 0.5 %) while the lowest one was recorded in untreated control (12.89 t ha^{-1}).

In 2006, the highest average grain yield was obtained in the variant treated with the three-quarter dose (i.e. 1.5 l ha^{-1}) of BASAGRAN SUPER – 15.56 t ha^{-1}. On the other hand, the lowest average yield was obtained in the variant treated with the registered dose of this herbicide (i.e. 2.0 l ha^{-1}).

Table 3. Grain yields obtained in individual experimental variants in years 2005 and 2006

Herbicide/dose (l ha^{-1})	Grain yield (t ha^{-1}) by 15% moisture content	
	2005	2006
CONTROL	12.89	14.57
CALLISTO 480 SC + ATPLUS 463 – 0.25 + (0.5 %)	14.38	15.03
CALLISTO 480 SC + ATPLUS 463 – 0.1875 + (0.5 %)	13.60	14.92
CALLISTO 480 SC + ATPLUS 463 – 0.125 + (0.5 %)	13.47	14.92
BASAGRAN SUPER – 2.0	13.07	14.45
BASAGRAN SUPER – 1.5	13.95	15.56
BASAGRAN SUPER – 1.0	13.30	15.24

CONCLUSION

The obtained results indicate that the PS1-Meter apparatus can be used for measurements of the efficacy of decreasing doses of herbicides CALLISTO 480 SC + ATPLUS 463 and BASAGRAN SUPER when killing the lambsquater *(Chenopodium album)* in stands of grain maize. It can be therefore concluded that the efficacy of reduced (half) doses of both herbicides (i.e. 0.125 l ha^{-1} of CALLISTO 480 SC + ATPLUS 463 and 1.0 l ha^{-1} of BASAGRAN SUPER) were sufficient and that the maize grain yields were not negatively affected.

REFERENCES

Chodová D., Mikulka J., Kočová M., 1995. Comparison of chlorophyll fluorescence and chlorophyll content in triazine-resistant and susceptible common groundsel (*Senecio vulgaris*). Ochrana Rostlin, 31, 185-194.

Haage I.C.P., Bastiaans L., Kempenaar C., 2002. Exploring options for improved low dose application based on the MLHD-technology. In: Proceedings 12th Symposium European Weed Research Society, Wageningen UR, 200-201.

Jalink H., van der Schoor, Frandas A., van Pijlen J. G., 1998. Chlorophyll fluorescence of Brassica oleracea seeds as a non-destructive marker for seed maturity and seed performance. Seed Science Research, (8), 437-443.

Kempenaar C., Groeneveld R.M.W., Uffing A.J.M., van der Weide R.Y., Wevers J., 2002. New insights and developments in the MLHD-concept of weed Control. In: Proceedings 12th Symposium European Weed Research Society, Wageningen UR, 98-99.

Klem K., 2006. Use of chlorophyll fluorescence in plant medicine (in Czech). Rostlinolékař, 1, 23-24.

MLHD PS1, 2004. Manual Version 2.0 September 2004. Wageningen, Plant Research International B.V., 18.

Norsworthy J. K., R. Talbert E., R. Hoagland E., 1998. Chlorophyll fluorescence for rapid detection of propanil-resistant barnyardgrass (*Echinochloa crus-galli*). Weed Science, 46, 163-169.

Smutný V., Kocurek V., Vondra M., 2006. Early assessment of herbicide efficacy using fluorescence camera. In: Proceedings of the 17th Czech and Slovak Plant Protection Conference, Praha, CAU Prague, 592-596.

Toivonen P.M.A., DeEll J R., 1998. Differences in chlorophyll fluorescence and chlorophyll content of broccoli associated with maturity and sampling section. Postharvest Biology and Technology, (14), 61-64.

Vondra M., Křen J., Smutný V., 2005. Use of chlorophyll fluorescence method for optimisation of herbicide doses. In: Proceedings of International Ph.D. Students Conference MendelNet´05 Agro, Brno, FA MUAF Brno, 1-8.

Vondra M., Smutný V., Křen J., 2006. Assessment of herbicide efficacy on redroot pigweed (*Amaranthus retroflexus*) using chlorophyll fluorescence. In: Proceedings of professional article „MUAF for growers“, Brno, FA MUAF Brno, 139-143.

Vondra M., Smutný V., Křen J., 2007. The use of reduced doses of herbicides CALLISTO 480 SC and BASAGRAN SUPER to Control *Cirsium arvense* in maize. In: Proceedings of professional papers „MUAF for growers“, Brno, FA MUAF Brno, 120-125.

OCENA SKUTECZNOŚCI RÓŻNYCH DAWEK HERBICYDÓW W ZWALCZANIU KOMOSY BIAŁEJ (*Chenopodium album*) PRZY UŻYCIU FLUORESCENCJI CHLOROFILU

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Streszczenie. Uzyskane wyniki wskazują, że w warunkach polowych aparat PS1-Meter może być wykorzystany do oceny skuteczności malejących dawek herbicydów CALLISTO 480 SC + ATPLUS 463 (surfaktant) oraz BASAGRAN SUPER w zwalczaniu komosy białej (*Chenopodium album*) w łanie kukurydzy na ziarno. Można sformułować wniosek, że jeżeli chodzi o wymienione herbicydy, to ich dawki mogą być zmniejszone do 50% wartości zalecanych bez ujemnego wpływu na plonowanie ziarna.

Słowa kluczowe: kukurydza na ziarno; miernik PS1-Meter; fluorescencja chlorofilu; herbicydy