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APPLICATION OF FOLIAR HERBICIDES IN PROSO MILLET CROPS IN RELATION TO GRAIN QUALITY

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A b s t r a c t. This paper presents the results of a study on the tolerance of proso millet to herbicides (2,4-D + fluroxypyr; tribenuron-methyl + fluroxypyr; MCPA – 2-methyl-4-chlorophenoxyacetic acid; dicamba + triasulfuron) foliar-applied at the tillering stage of proso millet, at the maximum rate (100%) and at a rate reduced by 50%. Plots without herbicide application were the control treatment. The experiment was carried out on a loess-derived soil (soil class II) under the climatic conditions of the central Lublin region, Poland. The study proved that herbicide application in millet crops was justified, because the herbicides (in particular 2,4-D + fluroxypyr and tribenuron-methyl + fluroxypyr) contributed to a statistically significant improvement in the grain chemical composition (especially to an increased content of essential amino acids, fat, selenium, and o-dihydroxy phenols). Moreover, no residues of active substances of the herbicides were found in the millet grain samples analysed. The herbicide rate reduced by 50% proved to be sufficient to ensure appropriate quality of millet grain.

K e y w o r d s: chemical composition of grain, herbicide rates, *Panicum miliaceum* L.

INTRODUCTION

Proso millet (*Panicum miliaceum* L.) originates from ancient China and, apart from that country, it is currently popular in Russia, Belarus, India, Japan and the USA. In Poland proso millet is an unpopular cereal and is included, alongside buckwheat and herbal plants, among the so-called small-scale crops. The reason is low yields of this crop (0.5-2.7 t ha^{-1}), its low economic importance, and difficult weed control (low competitiveness against weeds and sensitivity to herbicide application) (Hanna *et al*. 2004, Yakimovich 2010).

Millet groats are mainly obtained from proso millet, but in recent years their consumption has been observed to decline, which is due to the replacement of millet groats with buckwheat groats, rice, and oatmeal. According to many researchers, in terms of protein and fat content millet groats surpass popular barley and buckwheat groats. The energy value of millet groats is similar to that of rice, but their nutritional qualities are higher. The qualities of millet proteins are comparable to the biological value of the proteins of wheat, maize, bean, and peanut. Millet grains contain more amino acids, among others leucine and methionine, than other cereal grains. As far as the fat content is concerned, millet grains are second only to oat grains. Millet groats contain 1-3% of fat and 70-83% of starch. The oil composition in millet grains includes mainly valuable unsaturated fatty acids (Parthasarathy *et al*. 2006, Kalinova and Moudry 2006, Svirskis 2009). Proso millet is rich in mineral substances and vitamins, and its nutritional qualities are comparable to or better than those of common cereals (Ačko *et al.* 2012). In Africa and Asia, it is the main source of food for people (Shahidi and Chandrasekara 2013). In traditional Chinese medicine, tumors – even at an advanced stage – are treated using a very strict and consistent diet consisting of cereal grains (mainly millet grains) in 50%, vegetables in 30%, and juices in 20% (Ačko 2012). A diet rich in proso millet in patients subjected to chemotherapy prevents hair loss (Gardani *et al*. 2007). Protein concentrates of proso millet taken as part of the diet have been found to increase the plasma level of high-density lipoprotein (HDL) (Park *et al.* 2008, Liu *et al.* 2013). This protein also has protective effects against D-galactosamin-induced liver injury (Nishizawa *et al.* 2002, Liu *et al.* 2013). Millet starches may be used in the production of puffed starch food products and other food items (Wen *et al*. 2014).

Proso millet is very sensitive to herbicide application, especially to herbicide residues in the soil. The crop yield decreases significantly when the fields are heavily infested with weeds. The use of herbicides on millet is economically well-founded for guaranteed production of significant economic effect (Yakimovich 2005, Laptiev and Dolzhenko 2013). Weed control is generally carried out during the period from emergence to tillering, using a light harrow or a weeder harrow. The herbicide Chwastox Extra (MCPA) can also be used at an amount of 1.2-1.8 l ha^{-1} when plants reach the height of 10-15 cm. An earlier or later herbicide application causes plant damage and delays plant growth. In the case of heavy weed infestation, the pesticides used in the cultivation of oats can also be applied, but at low rates (Seefeldt *et al.* 1995, Stahlman *et al.* 2009).

As shown by experiments on weed control in buckwheat (a plant that is also sensitive to herbicides) (Wesołowski *et al.* 2007) and some herbal plants (thyme, common valerian, sweet basil) (Kwiatkowski 2007, 2009a, 2010), some herbicides not approved for use in these cultures can be successfully applied. This bodes well for attempts to test some herbicides also in millet crops.

The study hypothesised that the use of foliar-applied herbicides (recommended for weed control in oat crops) in millet crops would contribute to a better condition of the cereal crop and, in consequence, to a better chemical composition of grain compared to mechanical weed control alone (double harrowing). An assumption was also made that the herbicides applied at the rates reduced by ½ would not have a phytotoxic effect on the crop plant.

The aim of this study was to determine selected quality parameters of millet grain as affected by foliar-applied herbicides both at the maximum rates (100%) and at rates reduced by 50%.

MATERIALS AND METHODS

Experimental design. A field experiment in growing proso millet (cv. 'Jagna') was conducted in the period of 2010-2012 at the Czesławice Experimental Farm belonging to the University of Life Sciences in Lublin, Poland. The experiment was established on a grey-brown podzolic soil derived from loess (soil class II (based on Polish soil valuation classes). Before the experiment, the soil was characterised by high availability of essential nutrients (P = 158-165, K = 186-197, Mg = 68-73 mg 1 kg^{-1} soil). Humus content was 1.49-1.54%, while the soil pH (in 1 mole of KCl) – 6.0-6.4. The size of a single plot was 3 m x 5 m (15 m^2). The plots were drawn by lot using a split-plot design, in 4 replicates. Proso millet was sown with a precision seed drill at a rate of 4 kg ha^{-1}, at 15 cm row spacing, in the second 10-day period of May. In each year of the study, spring wheat was the previous crop for proso millet. Mineral NPK fertilisation, adjusted to the high soil nutrient availability, was as follows: N – 40, P – 30, K – 50 kg ha^{-1}. Conventional tillage was used. The experiment tested herbicides that were not approved for application in millet crops, but recommended for weed control in oat plantations (the Calendar of the Institute of Plant Protection in Poznań (2009) does not list any herbicides recommended for use in millet crops).

The experiment included the following factors:

I. Herbicide type: A. without herbicide (mechanical weed control) – control treatment) ; B. Gold 450 EC – 2.4-D + fluroxypyr (1.0 l ha^{-1}) – from 3-leaf stage to 1st node stage; C. Granstar Strong – tribenuron-methyl + fluroxypyr (15 g ha^{-1}) – from beginning till end of tillering; D. Chwastox Extra 300 SL – MCPA – 2-methyl-4-chlorophenoxyacetic acid (1.2 l ha^{-1}) – from beginning till end of tillering; E. Lintur 70 WG – dicamba + triasulfuron (0.12 kg ha^{-1}) – from beginning till end of tillering.

II. Herbicide rate: 1. 100%, 2. 50%.

The herbicides were applied at the above specified rates and at rates reduced by 50%, i.e.: Gold 450 EC (0.5 l ha^{-1}), Granstar Strong (7.5 g ha^{-1}), Chwastox Extra 300 SL (0.6 l ha^{-1}), Lintur 70 WG (0.06 kg ha^{-1}). Weed management in the control treatment (A) consisted in mechanical weed control (harrowing) before millet emergence (spike tooth harrow) and at the 2-3-leaf stage (weeder harrow). The herbicides (treatments B-E) were applied using a field sprayer under pressure of 0.25 MPa. The millet crop was harvested in the third 10-day period of August / first 10-day period of September (in 2010 the harvest in the third 10-day period of August was prevented by persistent rainfall).

Measurements. The following traits were analysed:

1. Thousand grain weight (TGW) of proso millet based on plants sampled from 1 m^2 of each plot.

2. Content of the following selected chemical components of millet grain: crude protein – determined by the near infrared (NIR) method using the Inframatic 9200 grain analyser; crude fat by the Soxhlet method (PN-A-74039:1964); crude fibre – gravimetrically (according to ASN 3428); total dihydroxyphenol content was expressed as caffeic acid equivalents – spectrophotometrically at wavelength of $\lambda = 725$ nm (Shimadzu 1800 spectrophotometer, Shimadzu Corp. Kyoto, Japan); selenium – atomic absorption spectrometry (Varian SpectrAA 280 FS spectrophotometer – Varian, Inc., Palo Alto, USA) with graphite furnace atomisation; grain amino acid content was determined by HPLC (AAA 400, Ingos, Prague, Czech Republic). The amino acids were separated by ion exchange chromatography. A 0.37 x 45 cm column was filled with ion-exchange resin (Ostion LG ANB, Tessek, Praha, Czech Republic). Amino acid identification was done using a photometric detector at wavelength of 570 nm for all amino acids, and only for Pro at 440 nm; tryptophan – ion exchange chromatography. The chemical composition of millet grain was evaluated when its moisture content was 12%.

3. Determination of residues of active substances of the herbicides in millet grain (quantitative analysis of the pesticides by liquid chromatography with a mass detector).

Calculations and statistical analysis. Qualitative analyses were carried out on samples from the individual plots. All study results were statistically tested by analysis of variance (ANOVA), determining the significance of differences using Tukey's test at a significance level of $p = 0.05$. The Essential Amino Acid Index (EAAI) was calculated as geometric mean of all essential amino acids in relation to the content of these amino acids in the egg reference protein (FAO 1985). The EAAI was calculated according to the following formula:

$$EAAI = \sqrt[n]{\left(\frac{a_1}{a_{1s}}\right) \times 100 \times ... \times \left(\frac{a_n}{a_{ns}}\right) \times 100} \quad (1)$$

where: $a_{1 \ldots} a_n$ – amino acid content in the tested protein, a_{1s} a_{ns} – amino acid content in the reference protein.

RESULTS

Thousand grain weight. Thousand grain weight (TGW) of proso millet was independent of the herbicide rate applied. However, statistically significant differences were found between weed control methods (Tab. 1). The herbicide 2.4-D + fluroxypyr resulted in a significantly higher value of TGW (on average by 6%) compared to the control treatment. The differences in TGW between the control treatment and the other treatments where the herbicides were applied (C, D, E) were within the limit of experimental error.

Table 1. TGW of proso millet (in g) and protein content in millet grain (% DM) – on average during the study period

Weed control method	TGW			Protein content		
	Herbicide rate		Mean	Herbicide rate		Mean
	100%	50%		100%	50%	
A. Control treatment – without herbicide			7.24			12.5
B. 2.4-D + fluroxypyr	7.76	7.71	7.73	11.9	11.3	11.6
C.tribenuron-methyl + fluroxypyr	7.70	7.60	7.60	12.1	11.8	11.9
D. MCPA	7.58	7.52	7.55	11.0	10.7	10.8
E. dicamba + triasulfuron	7.62	7.54	7.58	11.6	11.1	11.3
Mean	7.66	7.59	–	11.6	11.2	–
LSD $_{(0.05)}$ for: weed control methods		0.478			0.92	
herbicide rates		NS			NS	

NS – not significant

Protein content. The variation in herbicide rates had practically no effect on protein content in millet grain (Tab. 1). However, statistically significant differences were found for the individual weed control methods. The highest protein content in dry matter was determined in grain harvested from the control treatment without herbicide application (12.5%). The above protein content was significantly higher than that found under the conditions of treatment D (by as much as 1.7 percentage points (p.p.) and treatment E (1.2 p.p.). A significantly higher protein content in millet grain (on average by 1.1 p.p.) was also observed in the samples collected from treatment C (tribenuron-methyl + fluroxypyr) in relation to treatment D (MCPA).

Amino acid content. Amino acid content in millet grain was significantly dependent only on weed control method (Tab. 2). The data included in Table 2 show that the use of the herbicides 2.4-D + fluroxypyr and tribenuron-methyl in weed control in the millet crop contributed to an increase in the grain content of some amino acids, such as: glutamine, proline, cysteic acid, valine, and most importantly, it resulted in higher accumulation of valuable essential amino acids (lysine, methionine, tryptophan) in relation to the other weed control treatments. Furthermore, a trend was found towards a higher content of the other identified amino acids under the influence of the herbicides. The favourable amino acid composition of the millet crop treated with the herbicides 2.4-D + fluroxypyr and tribenuron-methyl + fluroxypyr was reflected in the high essential amino acid index (EAAI) which was respectively 71.5 and 69.8. Even though the application of the above-mentioned herbicides did not largely translate into an increase in protein content in millet grain (Tab. 1), their positive effect on the amino acid content proved to be unquestionable.

Table 2. Amino acid content in millet grain (mg g^{-1}) depending on weed control method – on average during the study period

Parameter	A – Control treatment (without herbicide)	B – 2.4-D + fluroxypyr	C – tribenuron-methyl + fluroxypyr	D – MCPA	E – dicamba + triasulfuron
Asp (asparagine)	6.06 a	6.44 a	6.35 a	6.01 a	6.23 a
Thr (threonine)	3.09 a	3.36 a	3.27 a	3.13 a	3.16 a
Ser (serine)	6.34 a	6.65 a	6.52 a	6.42 a	6.38 a
Glu (glutamine)	20.2 a	24.6 b	24.2 b	21.3 a	20.9 a
Pro (proline)	7.66 a	8.72 b	8.66 b	7.70 a	7.68 a
Gly (glysine)	2.64 a	2.88 a	2.78 a	2.72 a	2.69 a
Ala (alanine)	9.77 a	10.5 a	10.0 a	9.83 a	9.88 a
Cys-A (cysteine-A)	0.59 a	2.28 b	2.21 b	0.64 a	0.73 a
Val (valine)	4.29 a	4.83 b	4.79 b	4.23 a	4.32 a
Met (methionine)	1.78 a	3.15 b	3.18 b	1.86 a	1.82 a
Ile (isoleusine)	3.55 a	3.81 a	3.71 a	3.64 a	3.60 a
Leu (leusine)	11.3 a	12.5 a	11.9 a	11.7 a	12.0 a
Tyr (tyrosine)	2.66 a	2.91 a	2.87 a	2.69 a	2.75 a
Phe (phenylalanine)	5.17 a	5.66 a	5.52 a	5.34 a	5.29 a
His (histidine)	2.21 a	2.36 a	2.29 a	2.33 a	2.27 a
Lys (lysine)	1.43 a	1.99 b	1.96 b	1.49 a	1.46 a
Arg (arginine)	3.28 a	3.44 a	3.38 a	3.27 a	3.32 a
Trp (tryptophan)	3.89 a	5.77 b	5.62 b	3.78 a	3.90 a
EAAI**	56.7	71.5	69.8	58.0	58.3

* Means in rows with different letters (a-b) for individual weed control methods are significantly different (p = 0.05), ** EAAI – essential amino acid index

Fat and fibre content. The fat content in millet grain was significantly higher (on average by 0.5 p.p.) due to the application of the herbicides tribenuron-methyl + fluroxypyr and 2.4-D + fluroxypyr compared with the other treatments (A, D, E). Interestingly, a significantly higher fat content was also found in the case of treatment E (dicamba + triasulfuron) compared to treatment D (MCPA) – Table 3.

Considering the particular weed control treatments, we notice a significantly higher fibre content in grain from treatment D (MCPA) compared to the control treatment (without herbicide). The difference in fibre content in favour of treatment D was 1.3 p.p. The differences in the content of this component in the other treatments were within the limit of experimental error (Tab. 3).

Table 3. Fat content (% DM) and fibre content (% DM) in millet grain – on average during the study period

Weed control method	Fat content			Fibre content		
	Herbicide rate		Mean	Herbicide rate		Mean
	100%	50%		100%	50%	
A. Control treatment – without herbicide			3.1			11.3
B. 2.4-D + fluroxypyr	3.6	3.4	3.5	12.2	11.9	12.0
C.tribenuron-methyl + fluroxypyr	3.9	3.6	3.7	12.0	11.8	11.9
D. MCPA	3.0	2.9	2.9	12.7	12.5	12.6
E. dicamba + triasulfuron	3.3	3.2	3.2	12.4	11.9	12.1
Mean	3.4	3.2	–	12.3	12.0	–
LSD $_{(0.05)}$ for: weed control methods	0.26			1.21		
herbicide rates	NS			NS		

NS – not significant

O-dihydroxy phenol and selenium content. The chemical analysis of the millet grain shows that weed control using the herbicides 2.4-D + fluroxypyr and tribenuron-methyl + fluroxypyr promoted a significantly higher o-dihydroxy phenol content in millet grain relative to the control treatment and the treatment with the application of MCPA (Tab. 4).

Table 4. O-dihydroxy phenol content (g 100 g^{-1}) and selenium (Se) content in millet grain (mg kg^{-1}) – on average during the study period

Weed control method	O-dihydroxy phenol			Selenium content		
	Herbicide rate		Mean	Herbicide rate		Mean
	100%	50%		100%	50%	
A. Control treatment – without herbicide			0.037			18.6
B. 2.4-D + fluroxypyr	0.056	0.054	0.055	23.6	23.2	23.4
C.tribenuron-methyl + fluroxypyr	0.053	0.050	0.052	23.3	23.1	23.2
D. MCPA	0.039	0.036	0.037	18.7	18.1	18.4
E. dicamba + triasulfuron	0.049	0.048	0.048	19.4	18.9	19.1
Mean	0.049	0.047	–	23.6	23.2	–
LSD $_{(0.05)}$ for: weed control methods	0.0134			3.61		
herbicide rates	NS			NS		

NS – not significant

Selenium content in millet grain varied under the influence of weed control methods (Tab. 4). A significantly higher selenium content was found in the grain samples collected from the plots treated with the herbicides 2.4-D + fluroxypyr and tribenuron-methyl + fluroxypyr relative to the other treatments.

Evaluation of residues of active substances of the herbicides in millet grain. The investigation of residues of active substances of the herbicides in millet grain using quantitative analysis of the pesticides carried out by liquid chromatography with a mass detector did not reveal any content of the following biologically active substances in the millet grain: 2,4-D + fluroxypyr, tribenuron-methyl + fluroxypyr, dicamba + triasulfuron and MCPA. This means that the above-mentioned herbicides applied at the tillering stage of proso millet, both at the 50% and 100% rate, were completely safe in terms of grain quality and food safety (the grain did not contain any harmful chemical substances).

DISCUSSION

The research problem undertaken in this study is largely innovative, since in the literature of the subject there are few publications on the effects of herbicides on millet grain quality (the nutritional composition of grain). On the example of other cereal plants, researchers demonstrated a significant effect of herbicides on increased protein content in grain of spring barley (Kwiatkowski 2004, 2009b) and on the content of total protein, wet gluten and falling number and sedimentation value in winter wheat grain (Kwiatkowski and Kubecki 2006 Kwiatkowski *et al*., 2006). As commonly known, proso millet is considered to be a herbicide-sensitive plant and experiments on top dressing application of herbicides in this cereal crop primarily relate to the level of weed infestation and productivity (grain yield). The chemical composition of millet grain in the experiment in question was mainly dependent on the herbicides used and to a smaller extent on their rate and weather conditions. The individual study seasons contributed to significant differences only in grain protein content. The most favourable for the accumulation of protein in the grain was the slightly damp and warm year of 2012 (12.8%), the lowest protein content in grain was found but in very humid 2010 (10.4%). The content of this component in millet grain (10.8-12.5% DM), regardless of the experimental factors, was similar to the results presented by Baltensperger *et al.* (2004) and Kwiatkowski *et al*. (2015), whereas Ravindran (1991) found the average protein content in millet grain to be 14.4%. In the present study, starch content in millet grain was lower than that found by Kim *et al.* (2012).

The amino acid composition determines the nutritional value of protein. In nutrition, the following amino acids are of the greatest importance: lysine, sulphur amino acids, threonine, tryptophan, valine, and isoleucine (Biel and Maciorowski 2012). According to the research of Kalinova and Moudry (2006), despite the fact that the protein content in proso millet is at a level similar to that of wheat (about 11.6% of dry matter), proso millet protein is much richer in amino acids such as leusine, isoleusine and methionine, and contains less lysine and serine. In turn, Matuz *et al.* (2000) found in millet grain more aspartic acid, tyrosine, phenylalanine, and isoleucine, but less threonine, methionine, leucine, and proline. Ravindran (1992) proved that millet proteins were deficient in lysine, but contained adequate levels of the other essential amino acids. In the present study, the quality of the protein of this species was high, as confirmed by the calculated Essential Amino Acid Index (EAAI) which varied from 56.7 in the control treatment to 71.5 in the treatment with 2.4-D + fluroxypyr herbicide application. In their research, Kalinova and Moudry (2006) confirmed the high value of the millet grain protein, since the EAAI value for proso millet was 7% higher than that for wheat.

In the study by Raghuvir Singh Singh (2010), among the weed control measures, the application of atrazine at 0.5 kg a.i ha^{-1} as a pre-emergence herbicide along with one hand weeding at 30 days after sowing gave significantly the maximum grain yield (1.28 and 1.13 t ha^{-1}) than that of unweeded check and other treatments, except one hand weeding at 25 days after sowing. Significantly increased crop growth and grain yield after the application of terbutryn or atrazine were also obtained by Singh and Yadav (1990). In her study, Atanasova (2008) also found the applied herbicides (dicamba + triasulfuron and amidosulfuron + iodosulfuron methyl sodium) to have a positive effect on grain yield. In the study by Pradhan *et al.* (2010), two hand weeding at 20 and 45 DAS with a higher dose of oxyfluorfen (0.50 kg ha^{-1}) resulted in the highest grain yield, straw yield and harvest index, respectively, of finger millet than the medium dose of oxyfluorfen (0.25 kg ha^{-1}) combined with one or two hand weeding. Weed management resulted in significantly improved crop yield compared to weedy check. Moreover, the research by Sukhadia *et al.* (2000) and Ramachandra Prasad *et al*. (2010) confirmed that herbicides are economical and cost effective in managing weeds right from the initial stages, as compared to hand weeding.

The research of Kwiatkowski *et al.* (2015) reveals that proso millet, alongside spelt wheat, is a cereal which is best suited for organic farming and which tolerates the abandonment of the use of agricultural chemicals (including herbicides), because under the organic farming system it was characterised by a more favourable chemical composition (dietary fibre, dihydroxyphenols, macro- and micronutrients – N, K, Mg, Ca, Cu, Mn, Fe, Zn, Se) of grain compared to common wheat (spring and winter forms). The study results presented in this paper concerning the cultivation of proso millet under conventional farming show an opposite tendency, as herbicide-based weed management beneficially affected most of the grain quality characteristics being evaluated.

SUMMARY

1. To sum up the overall results of the study on the effects of the experimental factors on the chemical composition of millet grain, it should be concluded that herbicide application for weed control was justified. It was only in the case of grain protein content that higher accumulation of this component was found under the control treatment conditions relative to the treatments with herbicide weed control.

2. In the other cases, the herbicides (2.4-D + fluroxypyr and tribenuron-methyl + fluroxypyr) contributed to a statistically significant improvement in the chemical composition of millet grain (an increased content of essential amino acids, fat, selenium, and o-dihydroxy phenols). As far as the other components analysed are concerned (fibre), the effect of the herbicides was lower. The variation in herbicide rates (100%

and 50%) had almost no effect on the chemical composition of millet grain, The herbicides (2,4-D + fluroxypyr; tribenuron-methyl + fluroxypyr; MCPA; dicamba + triasulfuron) applied at both rates did not leave any residue in the millet grain harvested.

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APLIKACJA HERBICYDÓW NALISTNYCH W ZASIEWACH PROSA ZWYCZAJNEGO (*PANICUM MILIACEUM* L.) A JAKOŚĆ ZIARNA

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S t r e s z c z e n i e. Praca przedstawia wyniki badań dotyczące tolerancji prosa na herbicydy (2,4-D + fluroxypyr; tribenuron-methylowy + fluroxypyr; MCPA; dicamba + triasulfuron) stosowane dolistnie w fazie krzewienia prosa, w dawce maksymalnej (100%) i w dawce zmniejszonej o 50%. Poletka bez aplikacji herbicydu były obiektami kontrolnymi. Doświadczenie założono na glebie wytworzonej z lessu (klasa II) w środkowej Lubelszczyźnie. Udowodniono zasadność zastosowania herbicydów w zasiewach prosa, ponieważ te preparaty (zwłaszcza 2,4-D + fluroxypyr oraz tribenuron-methylowy + fluroxypyr) przyczyniły się do istotnej statystycznie poprawy składu chemicznego ziarna (szczególnie zwiększenia zawartości aminokwasów egzogennych, tłuszczu, selenu, o-dihydroksyfenoli). Ponadto nie stwierdzono żadnych pozostałości substancji aktywnych herbicydów w analizowanych próbach ziarna prosa. Dla zapewnienia odpowiedniej jakości ziarna prosa wystarczająca okazała się dawka herbicydów zmniejszona o 50%.

S ł o w a k l u c z o w e: skład chemiczny ziarna, dawki herbicydu, *Panicum miliaceum* L.