AGRONOMY SCIENCE
wcześniej – formerly
Annales UMCS sectio E Agricultura
VOL. LXXIII (4) 2018

 http://dx.doi.org/10.24326/asx.2018.4.8

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The influence of different methods of weed regulation on yielding and protein content in seeds of common bean (*Phaseolus vulgaris* L.)

Wpływ sposobu regulacji zachwaszczenia na plonowanie i zawartość białka w nasionach fasoli zwyczajnej (*Phaseolus vulgaris* L.)

Summary. The seeds of common bean, like other leguminous plants have high contents of protein with high biological value. Weed management is one of the most important problems in dry bean production. The paper presents results of a field experiment on the effect of different methods of weed regulation on the seeds yield and protein content of common bean ('Mela' and 'Aura'). The experiment was conducted in 2010–2012 on an individual farm located in Zamość district, Poland. The following methods of weed regulation were applied: A – no weeding, B – two-time weeding of inter-rows; C – Dual Gold 960 EC at 1.2 $dm^3 ha^{-1}$ + two-time weeding of inter-rows; D – Dual Gold 960 EC at 1.2 $dm^3 ha^{-1}$ + Basagran 480 SL at 2.5 $dm^3 ha^{-1}$ + Pantera 040 EC at 1 $dm^3 ha^{-1}$; E – Dual Gold 960 EC at 1.2 $dm^3 ha^{-1}$ + Basagran 480 SL at 1.25 $dm^3 ha^{-1}$ + Basagran 480 SL at 1.25 $dm^3 ha^{-1}$ + Pantera 040 EC at 1 $dm^3 ha^{-1}$. The highest seeds yield was obtained when three herbicides were applied (treatment E). Two-time inter-row weeding significantly increased the yield as compared to the unweeded control. But compared to herbicides, mechanical regulation was ineffective. This methods caused decreasing of seeds yield and protein content in comparison with chemical weed regulation.

Key words: bean cultivation technology, bentazon, common bean, seed yield, S-metolachlor, weed regulation method

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is an important world grain legume and vegetable. It occupies a significant place in human nutrition as an economically viable source of protein [Graham and Ranalli 1997, Santalla at al. 2001] as well as vitamins from group B, cellulose and mineral components. In Poland the area of common bean cultivation has recently amounted to more than 20 thousand hectares for dry seeds and it has been the main leguminous plant cultivated for consumer purposes [Łabuda 2010, Głowacka et al. 2015]. The technology of cultivation, except for the course of weather conditions, determines the yield of common bean. Weed control is one of major concerns of dry bean growers, as weeds can drastically reduce seeds yield and quality [Hekmat et al. 2007]. The most important element in common bean cultivation is keeping plantation free from weeds at least for the first 3–5 weeks after sowing [Dobrzański 1996, Chmielowiec and Borowy 1998]. When weeds accompany bean' plants throughout the vegetative period, the yield of seeds can be reduced by even as much as 60% [Hemss 1985]. The chemical composition of seeds can vary considerably as regards their quality and quantity, and it depends on many factors, such as cultivars, the phase of maturity, environment, weather conditions and the level of cultivation technology. The aim of the study was to determine the effect of weed regulation methods on seeds yield and content of proteins in two varieties of common bean under climatic conditions of south-eastern Poland.

MATERIAL AND METHODS

A field experiment was conducted in 2010–2012, in Frankamionka village (50°44′0″N, 23°39′0″E) in Zamość district. The experiment was set up with four replications. The experimental field was located on soil of clayey silt granulometric composition, slightly acidic (pH in 1 n KCl – 6.53), containing 1.9% organic matter, very rich in phosphorus (68.5 mg P_2O_5 in 100 g soil) and potassium (63.5 mg K_2O in 100 g soil).

The subject of the study was seeds yield and protein content of the 'Mela' and 'Aura' cultivars of common bean (*Phaseolus vulgaris* L.) cultivated for dry seeds. 'Mela' is a small seeds, very early, high-yielding cultivar, grown for dry seeds, suitable for cultivation all over Poland (except for a few northern regions).'Aura' is a medium seeds, early, high-cropping cultivar, with plants of medium height, lodging-resistant.

Five methods of weed regulation were investigated in the study:

A – no weeding control,

B – two-time weeding of inter-rows, the first three or four weeks after sowing and the second three weeks later;

C – Dual Gold 960 EC (a.i. S-metolachlor), 1–2 days after sowing at 1.2 dm^3 ha^{-1} + two times weeding of inter-rows, first four weeks after sowing and second three weeks later;

D – Dual Gold 960 EC, 1–2 days after sowing at 1.2 dm^3 ha^{-1} + Basagran 480 SL (a.i. bentazon), post-emergency four weeks after sowing at 2.5 dm^3 ha^{-1} + Pantera 040 EC (a.i. chizalofop–P-tefurylowy), post-emergence at 1 dm^3 ha^{-1};

E – Dual Gold 960 EC 1–2 days after sowing at 1.2 dm^3 ha^{-1} + Basagran 480 SL at 1.25 dm^3 ha^{-1} + Basagran 480 SL at 1.25 dm^3 ha^{-1} (first 3 weeks after sowing, and next ten days later) + Pantera 040 EC, post-emergence at 1 dm^3 ha^{-1}.

The size of one plot was 18 m^2 for sowing and 10.6 m^2 for harvesting. The beans were sown between 2 and 10 May, in 45 cm row space. The planting density of common bean was 400,000 plant per hectare. Mineral fertilization was applied uniformly in the following amounts: N – 30 kg ha^{-1}, P – 35 kg ha^{-1} and K – 96 kg ha^{-1} (in form: N – ammonium nitrate, P – granulated triplex superphosphate, K – potassium sulphate). All of the fertilizers were applied once before sowing. In every year of research, the forecrop was winter wheat. Tillage was conducted by the traditional method according to recommendations for common bean. Each years fungicide Pencozeb 80 WP at 2 kg ha^{-1} (a.i. mankozeb) was applied. Herbicides were applied with 'Pilmet Sano 2 P-030' rucksack sprayer.

Each year before the beans were harvested, 20 plants were randomly selected from each plot. The number of pods on one plant, the number and weight of the seeds of one plant, and the weight of 1,000 seeds were determined. Total and commercial seeds yield were determined after harvest. Content of total protein in seeds was also determined. The results were analysed statistically using variance analysis. Differences between means were evaluated with Tukey's test. Significance of differences was determined at 95% probability. The dependency between yield and the morphological characteristics of the plants was assessed using correlation coefficients with Statistica PL.

Table 1. Rainfall and air temperature in months IV–IX as compared to the long-term mean (1971–2005), according to the Meteorological Station in Zamość

Rainfall (mm)							
Years	IV	V	VI	VII	VIII	IX	Σ IV–IX
2010	21.3	106.7	62.7	143.5	83.3	103.4	417.5
2011	35.3	22.4	89.9	144.5	39.9	3.3	332.0
2012	59.7	55.4	101.1	28.4	59.7	34.3	304.3
Means for 1971–2005	44.1	65.5	78.9	98.4	54.3	52.2	341.0
Temperature							
2010	9.8	15.0	18.8	20.9	20.6	12.4	2981
2011	10.2	13.5	18.5	19.1	19.0	14.8	2905
2012	9.7	15.0	17.8	21.4	18.9	15.0	2989
Means for 1971–2005	7.9	14.1	16.8	18.4	17.8	18.9	2687

Data on the wather conditions prevailing during the course of the study were obtained from the meteorological station in Zamość (Tab. 1). The total precipitation during the vegetative period was the highest in the first year of the study and was also the highest than the long-term average. In the third year the total precipitation was much lower and evenly spread. Precipitation was very high in July, 2010 and 2011. The mean monthly air temperatures during the study were higher than the long-term average. 2010 and 2012 years were particularly warm; the temperature sum from April to September (calculated as the sum of the products of the mean temperature and the number of days in the month) was 2.989ºC while the long-term average was 2.687ºC.

RESULTS AND DISCUSSION

The weather conditions in the years of investigations had a major impact on the yield of common bean. The highest total and commercial seeds average yield of 1.790 kg and 1.718 kg per hectare respectively were obtained in 2012. The largest number of pods and seeds from plant were also determined in this vegetative season. Prusiński [2006] showed, that the yield of the common bean was higher in the vegetative season when total rainfall was lower but well spread than in other years. Large quantity of rainfalls at the time of blooming and tying the pods, i.e. in July has a particularly negative effect on yield. The smallest commercial seeds yield was in 2010, which was characterized by very large rainfalls in September, the time when common beans mature and are harvested.

Weed management is one of the most important problems facing dry bean growers. Weed species that commonly cause problems in dry bean production include common lamb's-quarters, redroot pigweed, wild mustard, common ragweed, smartweed, annual nightshades, green foxtail, arnyardgrass and gallant soldier [Chmielowiec and Borowy 2004, Soltani et al. 2005, Głowacka 2013]. Weeds compete with dry bean for light, moisture and nutrients, and can drastically reduce dry bean seeds yield and quality. Pulse crops grow slowly in the initial phase, which creates favourable conditions for the development of weeds. Dry bean is a short-season crop and because of its short physical characteristics it is very sensitive to weed interference, especially during early growth [Hakmat et al. 2008]. The quantity and quality of harvested dry beans depends on weed management. If no chemical substances are used to fight weeds, bean yield is very poor [Dobrzański 1996, Prusiński 2006]. In presented studies different methods of weed regulation influenced the yield of common bean seeds. Regardless of the cultivars, the lowest total and commercial seeds yield was obtained when no weed control was applied. The application of mechanical regulation of weeds was not effective, either. As comparred to herbicides, application of mechanical regulation significantly reduced the pods number in plants, as well as the number and the weight of seeds from one plant (Tab. 2). In the consequence, the crop of bean seeds was lower as compared to the remaining weeding methods. Trade yield was the smallest part of total yield when no weeding or only mechanical methods (twice inter-row cultivation) of weed regulations were applied. Also Soltani et al. [2007] reported, that white bean cannot compete with weeds effectively; as a result, weed interference results in large yield losses in white bean.

The use of herbicide pro-emergence (S-metolachlor) in connection with later two-time inter-row cultivation, considerably increased the total yield. S-metolachlor is a herbicide that has been used for weed management in maize, soybean and some market classes of dry bean to control a broad spectrum of grass and broadleaf weeds such as giant foxtail, yellow foxtail, large crabgrass, smooth crabgrass, fall panicum, witchgrass, redroot pigweed, American black nightshade and eastern black nightshade [Vencill 2002].

The data of the effectiveness of applying the S-metalochlor (Dual Gold 960 SL) are not conformable. Chmielowiec and Borowy [2004] noted a very good effect of metalochlor application. But in other studies the influence of this substance on broadleaf weeds such as redroot pigweed or hairy galinsoga was not so big [Dobrzański et al. 2000]. Soltani et al. [2006] reported, that visible injury after S-metolachlor application was transient with no adverse effect on plant height, shoot dry weight, and yield of common bean. In our study visible injury was no observed, and obtained data confirm the usefulness of S-metolachlor in cultivation of white bean 'Mela' and 'Aura'.

Table 2. Morphological features of common bean

Cultivar	Weed regulation		Traits			
			Number		Weight (g)	
			pods per plant	seeds per plant	seeds per plant	1000 seeds
'Mela'	A		6.0	12.3	2.13	173
	B		10.0	15.0	2.91	194
	C		12.9	27.9	6.10	218
	D		15.3	30.8	6.78	220
	E		18.2	32.1	7.14	223
	Mean		12.5	23.6	4.85	206
'Aura'	A		6.3	9.1	2.93	326
	B		8.5	11.3	4.00	360
	C		12.3	22.5	8.69	386
	D		11.2	24.5	9.28	382
	E		14.5	26.0	10.1	389
	Mean		10.6	18.7	6.99	363
Mean	A		6.1	10.7	2.53	250
	B		10.7	13.1	3.45	277
	C		13.7	25.0	7.39	302
	D		13.2	27.6	8.03	301
	E		16.4	28.9	8.62	306
2010			11.5	22.1	6.2	286
2011			11.8	19.9	5.7	283
2012			13.5	24.7	7.3	292
$LSD_{0.05}$ for:		V	1.3	3.3	0.8	11.0
		WR	1.5	5.4	0.9	14.2
		Y	1.5	5.4	0.9	14.0

Explanations: V – cultivar, WR – weeds regulations, Y – Year

The use of herbicide pro-emergence (S-metolachlor) in connection with later two-time inter-row cultivation, considerably increased the total yield. S-metolachlor is a herbicide that has been used for weed management in maize, soybean and some market classes of dry bean to control a broad spectrum of grass and broadleaf weeds such as giant foxtail, yellow foxtail, large crabgrass, smooth crabgrass, fall panicum, witchgrass, redroot pigweed, American black nightshade and eastern black nightshade [Vencill 2002].

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Post-emergence application of Bassagran (bentazon) and Pantera (chizalofop-P -tefurylowy) were most effective. Bentazon is a selective benzothiadiazole post-emergence herbicide that can provide effective control of broadleaved weeds including common lambsquarter, redroot pigweed, wild radish, hairy galinsoga, common groundsel, jimsonweed, ladysthumb, wild mustard, cocklebur, shepherdspurse and common chickweed [Soltani et al. 2005]. Post emergence application of benatzon can cause injury to common bean plant i.e. chlorosis, necrosis, growth and plant reduction. Wall [1995] reported up to 8% visual injury and up to 20% yield reduction in navy bean with the post-emergence application of bentazon. However, other studies have shown less than 3% of visual injury in black bean and less than 2% of visual injury in cranberry bean with post-emergence application of bentazon [Soltani et al. 2005]. Some studies have reported no yield reduction after post-emergence bentazon application [Blackshaw et al. 2000, Soltani et al. 2007, Hekmat et al. 2008].

Market classes of dry beans have shown different sensitivity to some herbicides [Urwin et al. 1996, Soltani et al. 2005]. In our studies post-emergence application of bentazon caused only minimal and transient visual injury to both cultivars of dry beans. Application of bentazon with a herbicide used to kill monocotyledonous weeds resulted in a significant increase in seeds yield, especially with a two-time application. Basagran (bentazon) – a herbicide used for post-emergence killing of dicotyledonous weed in common seed – is the only herbicide registered in Poland. Numerous studies conducted in Poland and abroad confirm its usefulness in weed control in common bean [Chmielowiec and Borowy 2004, Soltani et al. 2005, 2006, Prusiński 2006, Głowacka et al. 2015].

Table 3. Yield of common bean seeds (kg ha^{-1}) and protein content (%)

Cultivar	Weed regulation		Traits			
			total yield	comercial yield	protein content	yield of protein
'Mela'	A		298	268	18.9	50.7
	B		640	595	20.4	121
	C		1825	1733	21.9	379
	D		2168	2060	21.7	447
	E		2212	2101	22.1	464
	Mean		1429	1352	21.0	292
'Aura'	A		323	290	21.5	62.4
	B		799	743	23.8	177
	C		2519	2393	24.6	588
	D		2599	2469	24.1	595
	E		3022	2871	24.9	715
	Mean		1852	1760	23.8	427
Mean	A		310	279	20.2	56.6
	B		720	669	22.1	149
	C		2172	2063	23.3	484
	D		2384	2264	22.9	521
	E		2617	2486	23.5	590
2010			1600	1488	22.4	340
2011			1530	1457	21.9	314
2012			1790	1718	22.8	392
LSD for:		V	60	40	0.5	30.4
		WR	100	90	0.7	41.2
		Y	100	90	0.7	41.2

Explanations: V – cultivar, WR – weeds regulations, Y – Year

Legumes play an important part in human nutrition, they provide a good source of protein, which is 2–3 times that of cereal grains, and are a rich source of dietary fiber and starch [Osorio-Diaz et al. 2003]. Various types of beans are a staple food and a low-cost source of protein in many countries where protein energy malnutrition is prevalent. Content of total protein in common bean seeds differs considerably in the particular cultivars [Krupa and Solar-Śmietana 2005]. Martin-Cabrejas [2004] reported protein content of 20.9% but Korus et al. [2005] of 29.85%. The study conducted by Krupa and Solar-Śmietana [2003] confirm, that the content of proteins is the cultivar trait. In addition, they suggest that it depend on the size and the morphological structure of seeds. In the presented study the seeds of 'Aura' cultivar had a significantly larger content of total proteins i.e. 24.3% as compared to 'Mela' cultivar seeds – 21.5%. Apart from physiological properties, soil and climatic conditions during the vegetation period have a significant influence on chemical composition of bean seeds [Acosta 1996]. In the presented study the highest content of protein in seeds was found in 2012 (Tab. 3). The studies conducted by Łabuda and Papliński [2005] on the comparison of total nitrogen content in the seeds of nineteen bean cultivars demonstrated that it varied depending on years, as well as species and cultivar features. The influence of vegetative season on the content of protein in bean seeds was also confirmed by other studies [Krupa and Solar-Śmietana 2003]. In our study seeds from no-weed control had the smallest protein content. Apart from poor yield, protein production per one hectare was also smaller. Weed regulation limited to two-time interrow weeding (B) increased protein content in common bean seeds as compared to unweeded object (Tab. 3). Weeds regulation with the use of herbicides (C, D, E) significantly increased the content and yield of protein in seeds. The differences between the effect of these three methods used were insignificant. The interaction between weeds regulation methods and varieties of common bean was not significant.

Seed yield in common bean is generally expressed as a product of three components: number of pods per plant, seeds per pod and seed weight. According to Ayaz et al. [2004], the highest seed yields are generally obtained when all these components are maximized. In our study increase in the number of pods and seeds per plant was observed, when the yield of the seeds increased (Tab. 2). The weight of a hundred seeds differed significantly as regards to bean cultivars and weed regulation methods, but correlation coefficients between yield and weight of 1,000 seeds were statistically insignificant.

Nienhuis and Singh [1988] showed positive correlations between seed yield and yield components of dry bean. Głowacka [2008] demonstrated that seed yield was highly correlated with pods and seed number per plant, but not with seed number per pod or weight of a thousand seeds. Analysis of data obtained in our experiment confirm this conclusion. Common bean seeds yield was strongly and positively correlated with pods number per plant ($r = 0.913$, $p < 0.01$) and seeds number per plant ($r = 0.937$, $p < 0.01$).

CONCLUSION

1. The highest total and commercial yield of common bean seeds per hectare was obtained in 2012, the year with the most even distribution of precipitation.

2. The highest yield per hectare and the content of protein in seeds was obtained when the following weed regulationa were applied: Dual Gold 960 EC at 1.2 $dm^3\ ha^{-1}$ +

Basagran 480 SL at 1.25 dm^3 ha^{-1} + Basagran 480 SL at 1.25 dm^3 ha^{-1} + Pantera 040 EC at 1 dm^3 ha^{-1}. In this method also protein content in seeds and protein yield from hectare was the highest.

3. The seeds yield and content of total protein in seeds in the 'Aura' was higher as compared to the 'Mela'. The effect of different methods of weed regulation in both varieties was similar.

4. Pre-emergence herbicide Dual Gold 960 EC (S-metolachlor) is useful in cultivation of 'Mela' and 'Aura' white bean. The postemergence use of Bassagran 480 SL (bentazone) in two smaller doses is more beneficial than the application of a single higher dose. The choice of appropriate weed regulations methods should be connected with herbicides tolerance of the particular cultivars, economical profitability and local conditions.

REFERENCES

Acosta G., 1996. Effect of sowing date on the growth and seed yield of common bean (*Phaseolus vulgaris* L.) in highland environments. Field Crops Res. 49, 1–10.

Ayaz S., McKenzie B.A., Hill D.G., McNeil D.L., 2004. Variability in yield of four grain legume species in a subhumid temperate environment. I. Yields and harvest index. J. Agric. Sci. 142, 9–20.

Blackshaw R.E., Molnar J.L., Muendel H., Saindon G., Xiangju L., 2000. Integration of cropping practices and herbicides improves weed management in dry beans (*Phaseolus vulgaris*). Weed Technol. 14, 327–336, DOI:10.1614/0890-37x(2000)014[0327:IOCPAH]2.0.CO;2.

Chmielowiec P., Borowy A., 1998. Wpływ konkurencji chwastów na plonowanie fasoli zwykłej (*Phaseolus vulgaris* L.) uprawianej na suche nasiona. Zesz. Nauk. AR Krak., 333, 75–80.

Chmielowiec P., Borowy A., 2004. Ocena działania bentazonu i metolachloru w uprawie fasoli zwykłej (*Phaseolus vulgaris* L.) 'BONA'. Acta Sci. Pol., Hortorum Cultus 3(1), 75–87.

Dobrzański A., 1996. Krytyczne okresy konkurencji chwastów a racjonalne stosowanie herbicydów w uprawie warzyw. Prog. Plant Protect./Post. Ochr. Roś. 36(1), 110–116.

Głowacka A., 2008. Wpływ dolistnego nawożenia mikroelementami i środków ochrony roślin na plonowanie fasoli zwyczajnej (*Phaseolus vulgaris* L.). Biul. IHAR 248, 97–104.

Głowacka A., 2013. The influence of strip cropping on the state and degree of weed infestation in dent maize (*Zea mays* L.), common bean (*Phaseolus vulgaris* L.), and spring barley (*Hordeum vulgare* L.). Acta Agrobot. 66(1), 135–148, DOI: 10.5586/aa.2013.015.

Głowacka A., Klikocka H., Onuch J., 2015. Content of zinc and iron in common bean seeds (*Phaseolus vulgaris* L.) in different weed control methods. J. Elem. 20(2), 293–303, DOI: 10.5601/jelem.2014.19.2.499.

Graham P.H., Ranalli P., 1997. Common bean (*Phaseolus vulgaris* L.). Field Crop Res. 53, 131–146.

Hekmat S., Shropshire Ch., Soltani N., Sikkema P.H., 2007. Responses of dry beans (*Phaseolus vulgaris* L.) to sulfentrazone. Crop Protect. 26, 525–529, DOI:10.1016/j.cropro.2006.05.009.

Hekmat S., Soltani N., Shropshire Ch., Sikkema P.H., 2008. Effect of imazamox plus bentazon on dry bean (*Phaseolus vulgaris* L.). Crop Protect. 27, 1491–1494, DOI:10.1016/j.cropro.2008.07.008.

Heems H.D.J., 1985. The influence of competition on crop yield. Agric. Systems, 18, 81–93.

Korus J., Gumul D., Achremowicz B., 2005. Skład chemiczny pięciu nowych odmian fasoli zwyczajnej (*Phaseolus vulgaris* L.). Żywn. Nauka Technol. Jakość 4(45), 81–86.

Krupa U., Soral-Śmietana M., 2003. Nasiona fasoli – źródłem odżywczych i nieodżywczych makroskładników. Żywn. Nauka Technol. Jakość, 2(35) Supl., 99–108.

Krupa U., Soral-Śmietana M., 2005. Wpływ czynników fizycznych na dostępność enzymatyczną *in vitro* białek nasion fasoli *(Phaseolus* sp*)*. Żywn. Nauka Technol. Jakość, 2(43) Supl, 121–132.

Łabuda H. 2010. Runner bean (*Phaseolus coccineus* L.) – biology and use. Acta Sci. Pol., Hortorum Cultus 9(3), 117–132.

Łabuda H., Papliński R., 2005. Ocena nowych odmian fasoli zwykłej i fasoli wielokwiatowej na suche nasiona. In: Zmienność genetyczna i jej wykorzystanie w hodowli roślin ogrodniczych, B. Michalik, E. Żurawicz (ed.), Skierniewice, 161–166.

Martín-Cabrejas M.A., Sanfiz B., Vidal A., Mollá E., Esteban R., López-Andréu F.J., 2004. Effect of fermentation and autoclaving on dietary fiber fractions and antinutritional factors of beans (*Phaseolus vulgaris* L.). J. Agric. Food Chem. 52, 261–266.

Nienhuis J., Singh S.P., 1986. Combining ability analyses and relationships among yield, yield components, and architectural traits in dry bean. Crop Sci. 26, 21–27.

Osorio-Diaz P., Bello-Perez L.A., Sayago-Ayerdi S. G., Benitez-Reyes M. D., Tovar J., Paredes-Lopez O. 2003. Effect of processing and storage time on in vitro digestibility and resistant starch content of two bean (*Phaseolus vulgaris*) varieties. J. Sci. Food Agric. 83, 1283–1288, DOI:10.1002/jsfa.1413.

Prusiński J., 2006. Plonowanie fasoli zwykłej (*Phaseolus vulgaris* L.) w zależności od intensywności technologii uprawy. Cz. I. Wysokość i jakość plonu nasion oraz ich agrotechniczne uwarunkowania. Acta Sci. Pol., Agricultura 5(2), 65–76.

Santalla M., Amurrio J.M., de Ron A.M., 2001. Interrelationships between cropping systems for pod and seed quality components and breeding implications in common bean. Euphytica 121, 45–51.

Soltani N., Bawley S., Sikkema P.H., 2005. Responses of black and cranberry beans (*Phaseolus vulgaris*) to post-emergence herbicides. Crop Protect. 24, 15–21, DOI:10.1016/j.cropro.2004.06.003.

Soltani N., Shropshire Ch., Sikkema P.H., 2006. Effects of post-emergence application of bentazon and fomesafen on eight market classes of dry beans (*Phaseolus vulgaris* L.). Crop Protect. 25, 826–830. DOI:10.1016/j.cropro.2005.11.011.

Soltani N., Van Eerd L.L., Vyn R., Shropshire C., Sikkema P.H., 2007. Weed management in dry beans (*Phaseolus vulgaris*) with dimethenamid plus reduced doses of imazethapyr applied preplant incorporated. Crop Protect. 26(5), 739–745. DOI:10.1016/j.cropro.2006.06.013.

Urwin C.P., Wilson R.G., Mortensen D.A., 1996. Responses of dry edible bean (*Phaseolus vulgaris*) cultivars to four herbicides. Weed Technol. 10, 512–518, DOI:10.1017/S0890037 X0040355.

Wall D.A., 1995. Bentazon tank-mixtures for improved redwood pigweed (*Amaranthus retroflexus*) and common lambsquarters (*Chenopodium album*) control in navy beans (*Phaseolus vulgaris*). Weed Technol. 9, 610–616. DOI:10.1017/S0890037X00023927.

Vencill W.K., 2002. Herbicide Handbook, 8th ed. Weed Science Society of America, Lawrence, KS, 493 pp.

This work was supported by the Ministry of Science and Higher Education of Poland as the part of statutory activities of Department of Plant Cultivation Technology and Commodity, project number RKS/DS/6.

Streszczenie. Nasiona fasoli, tak jak i innych roślin strączkowych, zawierają dużo białka o wysokiej wartości biologicznej. Regulacja zachwaszczenia jest ważnym elementem technologii uprawy fasoli. W trzyletnich badaniach polowych określano wpływ różnych metod regulacji zachwaszczenia na plon nasion i zawartość białka fasoli zwyczajnej ('Aura' i 'Mela'). Doświadczenie przeprowadzono w latach 2010–2012 w gospodarstwie indywidualnym położonym w powiecie zamojskim (50°44′0″N, 23°39′0″E). Schemat badań obejmował metody regulacji zachwaszczenia: A – kontrola nieodchwaszczana, B – dwukrotne opielanie międzyrzędzi; C –

Dual Gold 960 EC w dawce 1,2 dm^3 ha^{-1} + dwukrotne opielanie międzyrzędzi; D – Dual Gold 960 EC w dawce 1,2 $dm^3 \cdot ha^{-1}$ + Basagran 480 SLw dawce 2,5 $dm^3 \cdot ha^{-1}$ + Pantera 040 EC w dawce 1 $dm^3 \cdot ha^{-1}$; E – Dual Gold 960 EC w dawce 1,2 $dm^3 \cdot ha^{-1}$ + Basagran 480 SL w dawce 1,25 $dm^3 \cdot ha^{-1}$ + Basagran 480 SL w dawce 1,25 $dm^3 \cdot ha^{-1}$ + Pantera 040 EC w dawce 1 $dm^3 \cdot ha^{-1}$. Najwyższy plon nasion fasoli otrzymano, gdy do regulacji zachwaszczenia użyto trzech herbicydów (kombinacja E). Dwukrotne opielanie międzyrzędzi istotnie zwiększyło plon nasion w porównaniu z nieodchwaszczaną kontrolą. Jednak w porównaniu z herbicydami mechaniczna regulacja nie była efektywna. Mechaniczna regulacja zachwaszczenia spowodowała obniżenie plonu nasion i zawartości białka w porównaniu z metodą chemiczną.

Słowa kluczowe: technologia uprawy, bentazon, fasola zwyczajna, plon nasion, S-metolachlor, metoda regulacji zachwaszczenia

Received: 19.11.2018
Accepted: 11.12.2018