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IMPACT OF PRESOWING SOAKING OF AMARANTH SEEDS IN SOLUTIONS OF GROWTH REGULATORS PART II. EFFECT OF TREATMENTS PROCESSING SEED MATERIAL ON GROWTH, DEVELOPMENT AND YIELD OF AMARANTH CV RAWA

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Abstract. The residual effect of presowing soaking seeds in solutions of commercial preparations containing GA_3 and IAA on the growth, development and yield of amaranth of the cultivar Rawa (*Amaranthus cruentus* L.) was assessed over 2010-2012. It was found that plants grown from treated seeds showed much more abundant growth than the control plants. This activity will be continued also in later developmental phases, although it not always contributed to an increase in plant yield. It appeared that conditioning did not mobilize seeds for more numerous emergences as had been expected when taking up the study. During the growth season the field crop remained under a strong influence of unfavourable weather conditions. Difficulties in obtaining satisfactory density after emergences as well as rainy and windy weather during harvest pose a threat to success in growing amaranth in field.

Key words: amaranth, growing in field, growth regulators, seeds soaking, seed yields

INTRODUCTION

Biological effects provoked in plants after the application of synthetic substances with a composition identical to natural hormones, auxins and giberelins, have already been used in agricultural practice and horticulture for more than 50 years. Of synthetic auxins, the one that found wider application is indoleacetic acid (IAA) , and in the large group of giberelins – giberelic acid – GA_3 [Carlson and Crovetti 1990, Sun and Gubler 2004, Zhao 2010, Tivari *et al.* 2011]. Depending on the expected response of plants, synthetic hormones are used in different developmental phases and on different organs. On world markets there are commercial preparations available dedicated particularly e.g. for regulating flowering of the individual cultivated species (in Poland – the

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Betokson tomatoes or the Pomonit apple tree). However, the use of synthetic growth regulators is much wider. They constitute important auxiliary means especially in fruit farming, vegetable growing and floriculture.

The review of literature indicates that the studies tested a possibility of use auxin preparations for improvement in taking roots of the following trees and shrubs grown in containers: *Berberis*, *Chamaecyparis*, *Ginkgo*, *Hypericum*, *Juniperus*, *Pachysandra*, *Physocarpus*, *Rosa* and *Thuja* [Falkowski and Szydło 2005] and to optimize the cultivation of strawberry [Marjańska-Cichoń and Sapieha-Waszkiewicz 2011] and blue honeysuckle *Lonicera caerulea* var. *kamtschatica* [Szot and Lipa 2012]. It was proved that the application of GA_3 can improve the yield and quality of vegetables from the temperate climate zone – carrot [Abbas 2010] and onion [Hye *et al.* 2002] – cultivated in conditions of hot climate and in salted soils in Pakistan. In India, in turn, there have been studies concerning the effect of giberelin and auxin on the yield of okra *Abmelmoschus esculentus* L. [Patil Patel 2010] and chilli [Kalshyam *et al.* 2011]. The effect of giberelic acid on the improvement of post-harvest duration of species from the genus *Zantedeschia* [Janowska and Jerzy 2003] and tulip [Szot and Rybczyński 2009] was tested, as well as the decorative values of poppy anemone *Anemone coronaria* [Janowska *et al.* 2009], varieties of freesia [Żurawik and Placek 2013], ajania pacifica *Ajania pacifica* [Zalewska and Antkowiak 2013] and Turkestan onion *Allium karataviense* [Pogroszewska *et al.* 2007]. The above mentioned experiments involving treating vegetative parts of plants with synthetic solutions of hormones by soaking or spraying, and this is the most common way of application of those preparations. Most often, although not in each case, the expected results have been recorded, such as a slightly higher survival rate of cut plants, elongation of tillers, more abundant flowering, increased yields of bulbs and tubers, etc.

Whereas the effects of seed conditioning in solutions of giberelin and auxin preparations for yielding of different species are less frequently described. In recent years the subjects of such experiments were, e.g.: spring barley jary [Naeem and Muhammad 2006], chickpea [Kaya *et al.* 2010], asparagus [Doran and Gudadhe 2012], rice [Ghodrat *et al.* 2013], flax [Rastogi *et al.* 2013] and onion [Islam *et al.* 2013]. The experiments were conducted in salted soils, in tropical countries, where conditions of growth, development and seed production of glycophytes are considerably difficult. However, there is no information about the residual effect of presowing treatment of amaranth seeds, although the mentioned authors indicated that seed conditioning of species of that kind has a positive effect on increasing germination capacity and early growth of seedlings.

Therefore a study was taken up aimed to determine the degree of effect of presowing application of biologically active substances of the type of growth hormones on the growth, flowering and maturing of amaranth of the cultivar Rawa growing in field. The research hypothesis was adopted that such treatments may constitute auxiliary means for the initial growth in field conditions, and that exogenous effect of growth hormones will affect further, more abundant growth and increased yield of plants. Growth experiments were planned based on the results of previous laboratory experiments that tested the effect of several combinations of use of two bioregulators (auxin and giberelin) applied in the form of commercial preparations (Betokson Super 025 SL and Pol-Gibrescol 800 SP). The results of those experiments were presented in part I of this paper [Jendrzejczak and Śmigerska 2014].

The aim of this study conducted in field conditions was to test the effects of soaking amaranth seeds prior to sowing on plant growth and development. The variants of use of both preparations that promised the best results in respect of the effect on the germination capacity of amaranth seeds after testing in laboratory conditions were chosen to be applied in the study.

MATERIAL AND METHODS

In the growing seasons 2010-2012 three replications of the field experiment were carried out, the subject of which was the amaranth cultivar Rawa. The experiment conducted in fields of the Experimental Station of Faculty of Agriculture and Biotechnology UTP in Mochełek near Bydgoszcz was established in the randomized block design. The factor treatments were the ways of processing of seed material:

1) soaking seeds in solution of the preparation Pol-Gibrescol 800 SP, with a concentration of 0.03%,
2) soaking seeds in solution of the preparation Betokson Super 025 SL, with a concentration of 2.0%,
3) soaking seeds in solution of a mixture of both preparations in the mentioned concentrations,
4) control – untreated seeds.

Soaking seeds lasted 8 hours at 15°C with access of light. After that the seeds were rinsed with water and dried laid in a thin layer for one day.

The experiments were conducted in Alfisol classified as the good rye complex in the quality class IVa, in 4 replications. The area of plots for harvest was 22.5 m^2. Seeds were sown in a row spacing of 40 cm, presowing soil fertilization amounted to: 60 $kg \cdot ha^{-1}$ P_2O_5 and 80 $kg \cdot ha^{-1}$ K_2O. Sowing was performed using a hand drill. Herbicides were not used, only interrows were mechanically weeded 2-3 times. Threshing was made at one stage with a small reaping thresher Seedmaster by Wintersteiger. After threshing, multi-stage cleaning and drying of seeds was performed (material after threshing was considerably contaminated with remains of plant parts and damp).

In the next seasons, the sowing time fell on 12, 10 and 12 May, and threshing – respectively: 8 October, 15 September and 8 October.

Observations included recording the Times of occurrence of successive developmental stages and the health state and cleanness of crops.

The following measurements were made:

- prior to harvest, the total number of plants in each plot was calculated,
- two Times, at the 6-8 proper leaf stage and before harvest, on 10 plants collected from each plot, the length and weight of the main tiller and its vegetative and generative part were measured (at the 6-8 leaf stage – only vegetative parts),
- after threshing and drying seeds, the yield from each plot was weighed, and the results were calculated into the weight with humidity15%.

Based on the data of the measurement of plant size in two developmental stages, density and seed yield, the proportions of the vegetative and generative part in the total length and weight of the tiller were calculated, as well as the seed weight per one plant.

In the middle of July each year in few plants (less than in 10% of single plants), inflorescence primordia appeared in the top part of the tiller. This growth stage was regarded as appropriate to pronounce the beginning of flowering. When making repeat measurements (at the end of August or on the first days of September), it was assumed that the place located right under the base of fully formed inflorescence means the end of the vegetative part of the tiller.

All results were subjected to the analysis of variance in the model appropriate for the way of establishing the experiment in the field. Analysis of variance was performed for single experiments and for the synthesis from the long-term period in the mixed model, where interactions of the years with constant factors were treated as random. The treatment means were compared using multiple Tukey's test.

Weather conditions during the study and the course of plant growing

In comparison with the average pluviothermal conditions of Bydgoszcz region, the growing period of amaranth in 2010-2012 was characterized by mostly quite high precipitation, and a higher temperature than the mean of the long-term period, particularly in 2011 and 2012 (Table 1).

Table 1. Some meteorological parameters in the growing season of amaranth in 2010-2012 compared to the means of this values in 1996-2011 (according to records of the weather point of the Experimental Station of the Department of Agriculture and the Biotechnology of the University of Technology and Life Sciences in Mochełek near Bydgoszcz)

Tabela 1. Wybrane parametry meteorologiczne w okresie wegetacji szarłatu w latach 2010-2012 na tle średnich tych wielkości w wieloleciu 1996-2011 (według notowań punktu meteorologicznego Stacji Doświadczalnej Wydziału Rolnictwa i Biotechnologii Uniwersytetu Technologiczno-Przyrodniczego w Mochełku koło Bydgoszczy)

Meteorological parameter Parametr meteorologiczny	Month Miesiąc	Year – Rok			Mean for years Średnio w latach 1996-2011
		2010	2011	2012	
Montly totals of air temperature Sumy miesięczne temperatury powietrza	May – maj	356.5	418.5	533.2	403.0
	June – czerwiec	501.0	531.0	528.0	486.0
	July – lipiec	669.6	542.5	601.4	576.6
	August – sierpień	570.4	548.7	582.8	554.9
	September – wrzesień	366.0	429.0	498.0	429.0
	total – suma	2463.5	2469.7	2743.4	2449.5
Montly totals of precipitation Sumy miesięczne opadów	May – maj	92.6	38.4	25.4	62.7
	June – czerwiec	18.1	100.8	133.8	45.3
	July – lipiec	107.4	132.5	115.6	84.8
	August – sierpień	150.7	67.7	51.8	68.7
	September – wrzesień	74.7	37.0	25.1	37.0
	total – suma	443.5	376.4	351.7	298.5
Hydrothermal coefficient Współczynnik hydrotermiczny	May – maj	2.60	0.92	0.48	1.56
	June – czerwiec	0.36	1.90	2.53	0.93
	July – lipiec	1.60	2.44	1.92	1.47
	August – sierpień	2.64	1.23	0.89	1.24
	September – wrzesień	2.04	0.86	0.50	0.86
	mean – średnia	1.85	1.47	1.26	1.21

The highest mean monthly precipitation total in the cultivation area falls in July, but in the period of this study this happened only in 2011, whereas in 2010 the rainfall maximum occurred later – in August, and in 2012 – earlier – in June. Apparently, the rainfall distribution in 2012 turned out to be the most favourable for plant growth, as the stage of plant vegetative growth falls in June. The rainy weather in the period of seed formation in 2010 is extremely unfavourable for maturing and threshing. The high precipitation total in April and May in 2010 contributed to good and even emergences, whereas spring droughts in both successive years resulted in slowing down and thinning out emergences. Amaranth plants responded strongly to excess or deficit of rainfalls during emergence and before harvest.

In 2010, in the maturing period of ripe, well grown plants, there occurred a long period of heavy rainfalls, making it impossible to perform harvest. This led to large losses in yields. In contrast to that, in 2012 the plant maturity stage fell to the warm and almost dry period. This favoured the even dying out of the plants and threshing proceeded without disturbances. For the whole growing period in 2010-2012 the plants did not show tendencies to lodging and presented a good health condition.

RESULTS

Field emergences of amaranth lasted about three weeks. For almost all June in each of the years of the study, the plant growth was very slow and only at the end of this month some acceleration of tiller elongation was observed, as well as more leaves.

In the middle of July each year, there were mostly 6-8 live leaves left on amaranth plants. About five leaves that formed earlier had already fallen, which was indicated by countable scars. Both the parts only with leaves and those with the inflorescence still elongated – a growth in both vegetative and generative part of tiller occurred. The number of leaves below the inflorescence increased up to 20-25. Also more rarely distributed leaves formed in many plants on the generative part of the tiller.

Differences between the treatments in the growth rate and tiller mass were already revealed in the middle of July (Table 2). On average in the long-term period, tillers of the control plants were then shorter by more than 16% and had the weight lower by almost 39% than the plants grown from presowing soaking seeds. The values of those parameters were affected by the chemical composition of bioregulator solutions. The plants grown from seeds soaked in a mixture of preparations had mostly longer but less massive tillers than those from seeds soaked in single preparations. Also the tillers of plants grown from seeds soaked in a solution of Pol-Gibrescol 880 SL were more often significantly longer and had a smaller weight than those from seeds soaked in a solution of Betokson.

On the turn of August and September, maturing amaranth plants from the control treatment still had statistically significantly shorter tillers (on average by about 24%) and with a smaller fresh weight (by as much as 71%) than the other plants. The average length of the vegetative part of amaranth tiller reached about 80 cm and was similar in all the years. The tillers of plants grown from seeds soaked prior to sowing in a solution of Pol-Gibrescol and its mixture with Betokson were usually statistically significantly longer. The average weight of leaved tiller was less than 188 g and showed a considerable differentiation both in the years and between the factor treatments. In 2011, where the sets were particularly ripe, the average tiller weight was two times higher as compared with 2010, but as much as three times higher than in 2012. The tillers with the highest vegetative weight were mostly formed by plants grown from seeds soaked in a solution of Betokson.

Table 2. Tiller length and the fresh mass of vegetative part of amaranth at the beginning of flowering and at the beginning of ripening and the percentage of the inflorescence part in the length and the total tiller mass before the harvest, depending on the method of seeds treating before sowing in 2010-2012, %

Tabela 2. Długość pędu i świeża masa części wegetatywnej roślin szarłatu w fazie początku kwitnienia i początku dojrzewania oraz udział części kwiatostanowej w długości i masie całkowitej pędu przed zbiorem w zależności od sposobu traktowania nasion przed siewem w latach 2010-2012, %

Specification Wyszczególnienie	Method for seeds treating before sowing Sposób traktowania nasion przed siewem	Tiller length – Długość pędu, cm				Fresh mass – Świeża masa, g			
		year – rok			mean średnia	year – rok			mean średnia
		2010	2011	2012	2010-2012	2010	2011	2012	2010-2012
Measurement at the beginning of flowering of the vegetative part of tiller Pomiar w fazie początku kwitnienia części wegetatywnej pędu	1. Pol-Gibrescol	28.5	34.1	33.4	32.0	38.8	41.4	57.2	45.8
	2. Betokson	31.7	24.1	26.6	27.5	54.1	56.9	57.8	56.3
	3. Pol-Gibrescol+Betokson	34.8	35.0	22.0	30.6	48.6	52.4	48.7	49.9
	4. Control – Kontrola	21.4	26.9	27.0	25.1	37.7	37.5	29.8	35.0
	mean – średnia	30.9	30.0	27.3	29.4	46.4	47.0	48.4	47.3
	$LSD_{0.05}$ – $NIR_{0,05}$	ns – ni	6.2	4.6	2.4	ns – ni	6.1	6.5	5.5
	significance of differences in years – istotność różnic w latach	–	–	–	1.6	–	–	–	ns – ni
	interaction – interakcja: years × treatments – lata × zabiegi	–	–	–	ist.	–	–	–	ist.
Measurement after ending the growth in the vegetative part of the stem Pomiar po zakończeniu wzrostu części wegetatywnej pędu	1. Pol-Gibrescol	78.4	82.9	86.9	82.7	153.9	321.0	193.3	207.0
	2. Betokson	82.0	82.2	73.9	79.4	194.2	520.0	103.3	261.2
	3. Pol-Gibrescol+Betokson	95.4	83.7	76.8	85.3	183.9	283.0	98.8	186.0
	4. Control – Kontrola	57.8	69.6	60.4	62.6	57.1	186.1	37.9	95.9
	mean – średnia	78.4	79.6	74.5	77.5	147.3	327.5	108.3	187.5
	$LSD_{0.05}$ – $NIR_{0,05}$	15.0	13.3	7.6	7.4	26.6	211.6	24.3	75.4
	significance of differences in years – istotność różnic w latach	–	–	–	ns – ni	–	–	–	53.5
	interaction – interakcja: years × treatments – lata × zabiegi	–	–	–	ist.	–	–	–	ist.
Percentage of the inflorescence in tiller size before the harvest Udział kwiatostanu w wielkości pędu przed zbiorem	1. Pol-Gibrescol	38.2	37.4	32.3	36.0	47.8	36.8	33.9	39.5
	2. Betokson	38.5	37.3	25.2	33.7	46.7	26.6	20.4	31.2
	3. Pol-Gibrescol+Betokson	34.6	36.7	23.5	31.6	42.0	35.2	18.6	31.9
	4. Control – Kontrola	37.3	35.3	28.0	33.5	40.5	37.5	33.9	37.3
	mean – średnia	37.2	36.7	27.2	33.7	44.3	34.0	26.7	35.0
	$LSD_{0.05}$ – $NIR_{0,05}$	ns – ni	6.1	6.5	5.5	ns – ni	ns – ni	7.0	ns – ni
	significance of differences in years – istotność różnic w latach	–	–	–	ns – ni	–	–	–	6.0
	interaction – interakcja: years × treatments – lata × zabiegi	–	–	–	ist.	–	–	–	ist.

To generalize the observations resulting from comparison of two measurements of the tiller vegetative part made at 6-7-week interval, it may be concluded that in plants that used to grow slowly before, a rapid increase in size occurs in this period, while the multiplicity of the tiller vegetative part length increase was similar in all the years and amounted to slightly more than 2.7-fold, and of weight (at a higher variability) – nearly 4-fold.

At the stage of the beginning of maturing, the plants usually reached a height of about 1.2 m, although in the control treatment in 2010 and 2012 they were on average lower than in 2011 and the lowest in comparison with the treatments where processed seeds were sown. Differences in the effect of bioregulator types on the plant height and inflorescence length were generally small. The plants formed the longest inflorescences, with a length of even more than 0.5 m, in 2011, whereas in 2012 their length rarely exceeded 0.4 m. On average, one third of the whole plant length fell for the inflorescence part of the tiller. In 2010 and 2011 its percentage was even higher, whereas in the last year of the experiments it rarely exceeded 30%. Comparison of those data with the weather course in August and September in the successive years indicates that the total precipitation at that time has a substantial effect on the elongation of the inflorescence part of tillers. Hence the dry weather prevailing in those months of 2012 could result in a smaller growth in amaranth inflorescences.

Correlating the length and weight of the inflorescence part, examined in the second measurement time, is very high ($r = 0.86$), which means that a longer inflorescence also weighed more. However, it should be emphasized that this measurement fell in the period where seeds were not formed yet. A big part of the amaranth inflorescence is the perianth, which makes a burden in the process of maturing and withering of plants, separating from seeds with difficulty. Nevertheless, correlation coefficients of the length and fresh weight of inflorescence with the number of seeds from one plant are statistically significant and amounted to $r = 0.74$ and $r = 0.75$, respectively, which means that more seeds are formed in larger inflorescences.

The effects of the research factor were modified not only by variability of the weather conditions in the years of the study but also by the plant density per an area unit (Table 3).

The weather conditions during harvest had a higher effect on the quantity of yield gathered from amaranth crops in the years of the study than the experimental factor. In 2010 the precipitation during plant maturation, in August and September, exceeded the long-term standard twofold (Table 1). Ripe sets wilted standing and the seeds (nuts) were knocked from breaking panicles by rain. Such obstacles before and during harvest were not noted in the other years. Therefore, in spite of a good state of the plantation and sufficient density, the yields harvested in 2010 were very small, whereas in the following years, at a small plant density, the yield quantity was quite satisfactory. Due to a considerable dispersion of the number of plants in replications, large differences between the treatment means in 2011 i 2012 turned out to be statistically insignificant. The analysis of variance did not show significant differences for the seed yield from an area unit and from single plants.

Table 3. Density before harvest, seed yield and weight of seeds per plant depending on method of seeds treating before sowing in 2010-2012
Tabela 3. Obsada przed zbiorem, plon nasion oraz masa nasion z 1 rośliny w zależności od sposobu traktowania nasion przed siewem w latach 2010-2012

Specification Wyszczególnienie	Method of seeds treating before sowing Sposób traktowania nasion przed siewem	Year – Rok			Mean Średnia 2010-2012
		2010	2011	2012	
Density before harvest no.·m^{-2} Obsada roślin przed zbiorem szt.·m^{-2}	1. Pol-Gibrescol	19.2	5.3	11.4	12.0
	2. Betokson	24.5	3.9	6.1	11.5
	3. Pol-Gibrescol+Betokson	32.8	4.0	7.2	14.7
	4. Kontrola (Control)	20.4	5.2	15.2	13.6
	mean – średnia	24.2	4.6	10.0	13.0
	$LSD_{0.05}$ – $NIR_{0,05}$ for treatments – dla zabiegów	ns – ni	ns – ni	ns – ni	ns – ni
	$LSD_{0.05}$ – $NIR_{0,05}$ for years – dla lat	–	–	–	6.2
	years × tratments – lata × zabiegi	–	–	–	ist.
Seed yield Plon nasion Mg·ha^{-1}	1. Pol-Gibrescol	0.192	1.459	0.918	0.856
	2. Betokson	0.251	1.054	1.030	0.778
	3. Pol-Gibrescol+Betokson	0.387	1.714	0.438	0.846
	4. Kontrola (Control)	0.204	1.161	1.142	0.735
	mean – średnia	0.259	1.347	0.882	0.804
	$LSD_{0.05}$ – $NIR_{0,05}$ for treatments – dla zabiegów	0.168	ns – ni	ns – ni	ns – ni
	$LSD_{0.05}$ – $NIR_{0,05}$ for years – dla lat	–	–	–	0.351
	years × tratments – lata × zabiegi	–	–	–	ns – ni
Weight of seeds per 1 plant Masa nasion z 1 rośliny g	1. Pol-Gibrescol	1.00	27.53	8.05	12.19
	2. Betokson	1.02	27.03	16.89	14.98
	3. Pol-Gibrescol+Betokson	1.18	42.85	6.08	16.70
	4. Kontrola (Control)	1.27	25.90	5.80	10.99
	mean – średnia	1.12	30.83	9.21	13.72
	$LSD_{0.05}$ – $NIR_{0,05}$ for treatments – dla zabiegów	ns – ni	ns – ni	ns – ni	ns – ni
	$LSD_{0.05}$ – $NIR_{0,05}$ for years – dla lat	–	–	–	5.92
	years × tratments – lata × zabiegi	–	–	–	ns – ni

DISCUSSION

The characteristic feature of the studied species is slow emergences, often appearing only after two – three weeks from sowing and sometimes lasting for next several days. This unfavourable phenomenon is connected with the occurrence of a hard fruit cover on amaranth nuts, through which the sprout probably shoots break through easier at a high temperature during germination (which was indicated in the laboratory experiment). In conditions of the amaranth cultivation region, the mean daily air temperature in the middle of May did not exceed 13ºC, which did not ensure the thermal optimum for this process. Insufficient soil moisture during germination and the beginning of emergences is another, exceptionally unfavourable reason for poor emergences of amaranth. Seed leaves, after getting out above the soil surface, are very small, even hardly noticeable, and a week radicle reaches very shallowly. If the top layer of soil is dried at that time, seedlings dry fast and die out. Therefore after sowing amaranth one can expect either even and dense emergences or hardly any emergences. The initial period of plant growth may determine the course of all further plant growth, which is confirmed by observations and the results of experiments conducted in Poland [Ścigalska and Klima 1997, Starczewski and Maksymiak 2001, Ogrodowska *et al.*

2011] and, among others, in the USA [Stallknecht and Schulz-Schaeffer 1993], in Austria [Gimplinger *et al.* 2007] and in Lithuania [Svirskis 2003].

Results of early appearing weed infestation in conditions of the lack of herbicide protection are a serious threat to the crop success. In this field experiment, weed infestation with barnyard grass and green bristle grass and later, also with white goose-foot and green amaranth, appearing in May, pose the highest threat to the amaranth crops, whereas the emergences of barnyard grass and goose-foot appear in large numbers then. From the literature review it follows that the application of spraying with the preparation Fusilade Forte 150 EC turned out to be very effective in grass control [Deryło and Chudzik 2012]. Such treatments were also performer in the present experiment and they effectively limited the amount of grasses in the research area. The weed infestation of amaranth crops, at the lack of carefulness in mechanical weeding, is a factor often disqualifying a plantation [Stallknecht and Schulz-Schaeffer 1993, Myers 1996, Apaza *et al.* 2002, Gimplinger *et al.* 2007].

In the present experiment, amaranth plants did not show any symptoms of infestation by fungal diseases. This confirms the observations of Pusz [2009] about a high resistant of this species to pathogenic fungi, in which it differs from other amaranth species. Only sporadically small signs of colonizing leaves by aphids were observed.

The above-mentioned authors notice a high variability of amaranth yields and difficulty in harvest and handling the material after harvesting. Mean yields gathered in the present study did not differ from those given by the cited scientists, according to whom on average about 1 ton of pure seeds per hectare is obtained. In the climatic conditions of south-east Poland, amaranth harvest is performer after the occurrence of ground frosts, which effectively destroy aboveground parts of plants, including leaves [Ścigalska and Klima 1997, Ogrodowska *et al.* 2011]. In the area of Bydgoszcz ground frosts often appears later, but they are preceded by rainy weather, which makes the combine harvest difficult. Also a tendency to seed shedding before harvest makes a serious cultivation problem. In large and long growing inflorescences of amaranth seeds mature unevenly, and those older ones are knocked out by wind and rain. Fitterer *et al.* [1996] cite opinions that the losses caused by that phenomenon may reach up to 50% of the potential yield. In spite of seed shedding before harvest, amaranth does not pose a threat of field weed infestation. The seeds lose germination capacity in soil, which was proved in the study by Kudska *et al.* [2012]. It is worth mentioning that it was found that amaranth leaves improving stand for onion and carrot and worsening – for radish [Tejeda-Sartorius *et al.* 2011]. Nevertheless, Brenner's [1995] observation of amaranth ability to cross with weeds from the same genus is worrying.

Growth response of the amaranth cultivar Rawa derived from seeds soaked in solutions of bioregulators showed in a statistically significant increase in plant size in comparison with the control treatment. A similar residual effect of seed priming of various plant species with the use of solutions of GA_3, IAA, as well as osmo-conditioning seeds combined with those preparations, was reported by Naeem and Muhammad [2006], Kaya *et al.* [2010], Doran and Gudadhe [2012], Ghodrat *et al.* [2013] and Rastogi *et al.* [2013]. In contrast to the results obtained during the present study, the cited authors most often also found a considerable increase in seed yields of plants derived from seeds treated prior to sowing with solutions of bioregulators, particularly – giberelin. In the present study, presowing soaking seeds had a favourable effect on the vegetative growth of amaranth. This effect was also continued in the development phase, although it did not contribute to an increase in plant yield. It turned out that tested treatments did not mobilize seeds to more numerous emergences, as it had been assumed while planning the experiment.

The results of the present study remained under a strong modifying effect of the outside conditions, which may suggest the lack of final effectiveness of the tested treatments. However, the strong secondary growth response of amaranth to presowing seed soaking in both preparations suggests that treating seeds with them can be considered in growing this species in field. At a very small sowing rate and low costs, this treatment is not easy to perform. It can turn out to be a well auxiliary method for increasing the survival rate of emerging plants.

CONCLUSIONS

1. Conditioning seeds of amaranth of the cultivar Rawa in solutions of preparations Pol-Gibrescol 800 SP, Betokson Super 025 SL and their mixture have no effect on the plant density, which was dependent on soil humidity during germination and emergences.

2. Residual effect of presowing seeds soaking was a statistically significant increase in the size of plant vegetative part as well as the length and fresh weight of the inflorescence part of tillers as compared with the control treatment.

3. Unevenness of post-emergence density made it impossible to state the directed effect of presowing seed conditioning on the height of amaranth yield.

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WPŁYW NASTĘPCZY PRZEDSIEWNEGO MOCZENIA NASION SZARŁATU UPRAWNEGO W ROZTWORACH REGULATORÓW WZROSTU CZ. II. WPŁYW ZABIEGÓW USZLACHETNIAJĄCYCH MATERIAŁ SIEWNY NA WZROST, ROZWÓJ I PLONOWANIE SZARŁATU ODMIANY RAWA

Streszczenie. W latach 2010-2012 oceniano wpływ następczy przedsiewnego moczenia nasion w roztworach preparatów handlowych zawierających GA_3 i IAA na wzrost, rozwój i plonowanie szarłatu krwistego odmiany Rawa (*Amaranthus cruentus* L.). Stwierdzono, że rośliny pochodzące z nasion traktowanych przejawiały znacznie bujniejszy wzrost niż rośliny kontrolne. Działanie to miało kontynuację również w późniejszych fazach rozwoju, choć nie zawsze przyczyniało się do zwiększenia plonowania roślin. Jak się okazało, zabiegi kondycjonowania nie mobilizowały nasion do liczniejszych wschodów, na co liczono przystępując do badań. Uprawa polowa pozostawała pod silnym wpływem niekorzystnych warunków pogodowych w trakcie wegetacji. Zagrożeniem dla sukcesu w uprawie polowej szarłatu są trudności w uzyskaniu zadowalającej obsady po wschodach oraz deszczowa i wietrzna pogoda w trakcie zbiorów.

Słowa kluczowe: moczenie nasion, plony nasion, regulatory wzrostu, szarłat uprawny, uprawa polowa

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