EFFECT OF TRIACONTANOL ON THE PRODUCTIVITY OF YELLOW LUPIN (Lupinus luteus L.) PLANTS

WPŁYW TRIACONTANOLU NA PRODUJCYJNOŚĆ ROŚLIN ŁUBINU ŻÓŁTEGO (Lupinus luteus L.)

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Abstract

A two-factor field experiment under strict conditions was made over 2007-2009 and aimed to evaluate the applicability of triacontanol (TRIA) to Mister yellow lupin (*Lupinus luteus* L.) seed production. TRIA was applied at two development stages: at the beginning of main-stem and lateral-shoot blooming at the concentration of 0.5; 1 and 2 mg·dm^{-3}. Plant spraying with water constituted the control. Triacontanol significantly increased yellow lupin yielding. Under more favourable moisture conditions it was sufficient to apply 0.5-1 mg·dm^{-3}, and under less favourable conditions – 2 mg·dm^{-3}. A higher yellow lupin productivity was due to the effect of triacontanol on the increase in the value of the coefficient of the use of biological potential of the plants. There was identified a significant effect of the TRIA application date neither on the yellow lupin yielding nor on the structural seed yield components.

Keywords: yellow lupin, triacontanol, biological yielding potential of plants

Streszczenie

Ścisłe dwuczynnikowe doświadczenie polowe wykonano w latach 2007-2009 w celu określenia przydatności triacontanolu (TRIA) w uprawie nasiennej łubinu żółtego (*Lupinus luteus* L.) odmiany Mister. TRIA zastosowano w dwóch fazach rozwojowych roślin – na początku kwitnienia kwiatów na pędzie głównym i na pędach bocznych w stężeniu 0,5; 1 i 2 mg·dm^{-3}. Oprysk roślin wodą stanowił kontrolę. Tricaontanol wpłynął na istotny wzrost plonowania łubinu żółtego. W korzystniejszych warunkach wilgotnościowych wystarczająca okazała się dawka 0,5 – 1,0 mg·dm^{-3}, a w mniej korzystnych 2 mg·dm^{-3}. Wyższa produkcyjność łubinu po zastosowaniu triacontanolu wynikała ze zwiększenia wykorzystania przez rośliny potencjału biologicznego. Nie stwierdzono istotnego wpływu terminu zastosowania TRIA na plonowanie łubinu i strukturalne elementy plonu nasion.

Słowa kluczowe: łubin żółty, triacontanol, biologiczny potencjał plonowania roślin

Streszczenie szczegółowe

Ścisłe dwuczynnikowe doświadczenie polowe wykonano w latach 2007-2009 w Mochełku, w Stacji Badawczej Wydziału Rolnictwa i Biotechnologii Uniwersytetu Technologiczno-Przyrodniczego w Bydgoszczy. Celem badań była ocena przydatności traicontanolu (TRIA) w uprawie nasiennej łubinu żółtego (*Lupinus luteus* L.) odmiany Mister. TRIA zastosowano dwukrotnie: na początku kwitnienia kwiatów na pędzie głównym (odpowiednio w latach badań: 9., 12. i 26. czerwca) i na pędach bocznych (odpowiednio w latach badań: 19. i 20. czerwca oraz 10. lipca) w stężeniu 0,5; 1 i 2 mg·dm^{-3}. Oprysk roślin wodą stanowił kontrolę. Okres badań charakteryzował się odmiennymi dla rozwoju roślin i plonowania łubinu żółtego warunkami meteorologicznymi. W latach 2007 i 2009 ciepła i deszczowa pogoda w okresie rozwoju wegetatywnego i generatywnego sprzyjała obfitemu kwitnieniu i zawiązywaniu strąków, zaś posuszne warunki w końcu lipca i na początku sierpnia dojrzewaniu roślin. Z kolei warunki pogodowe w 2008 roku były dla łubinu wyjątkowo niekorzystne, zwłaszcza w początkowym okresie wzrostu, a następnie w fazie generatywnej (tab. 1). Zróżnicowanie liczby kwiatów na jednej roślinie w latach badań wahało się od 38,4 do 57,5 a średni w latach badań współczynnik wykorzystania potencjału biologicznego na roślinach kontrolnych (bez stosowania TRIA) wynosił 25,6% na pędzie głównym (rys. 1) i 5,4% na pędach bocznych (rys. 2). Zastosowane dawki TRIA wpłynęły na zwiększenie jego wartości odpowiednio do 32,2% i 6,71% oraz istotny wzrost plonu nasion, głównie w wyniku korzystnego wpływu triacontanolu na podniesienie współczynnika wykorzystania potencjału biologicznego roślin na pędzie głównym. W korzystnych warunkach wilgotnościowych wystarczająca była dawka 0,5-1 mg·dm^{-3}, a w niekorzystnych – 2 mg·dm^{-3} (tab. 3). Wzrastające dawki TRIA wpływały też na istotny wzrost wartości strukturalnych elementów plonowania łubinu (oprócz pędów bocznych) (rys. 3-5), z wyjątkiem masy 1000 nasion. Najkorzystniejsze efekty uzyskano po użyciu TRIA w najwyższym stężeniu. Nie stwierdzono istotnego wpływu terminu zastosowania TRIA na plonowanie łubinu żółtego i strukturalne elementy plonu nasion. Większość badań nad wykorzystaniem TRIA w uprawie roślin rolniczych, warzywnych i ozdobnych wykonano w Azji, gdzie regulator ten stosowany jest na szeroką skalę produkcyjną. W Polsce wykonano szereg badań nad wykorzystaniem różnych regulatorów wzrostu w celu zwiększenia wykorzystania potencjału produkcyjnego przez rośliny strączkowe, jednak żaden z nich nie wszedł do praktyki rolniczej. Wyjątkowo obiecujące wyniki badań nad triacontanolem w uprawie nasiennej łubinu żółtego wymagają zapewne dalszych doświadczeń, także nad innymi gatunkami roślin strączkowych i w różnych warunkach agro-klimatycznych.

Introduction

The key role in the control of the number of flowers and pods per legume plant is played to a number of factors demonstrating a comprehensive effect; most importantly, the weather conditions pattern [9,17], plant nutrition [1], competition for assimilates between vegetative and generative plant parts [12] and their hormonal economy [2].

Triacontanol (TRIA) is a 30-carbon saturated alcohol acting as a growth regulator [8]. Applied at very low concentrations for legumes, it affects many physiological processes, e.g. it triggers net assimilation and the activity of nitrate reductase, increases the contents of leghemoglobin in nodules and N in leaves and in seeds [11], which enhances yielding [3,6,10,13,18].

The working hypothesis of the present research assumes that foliar application of triacontanol will increase the plant supply with nitrogen, and thus limit flower and podsets shedding in yellow lupin plants, enhance yielding and the biological use of the plant potential. The aim of the present research was to determine the optimal dose and date of triacontanol application in yellow lupin seed production.

Materials and methods

A two-factor field experiment under strict conditions in randomised block design in 4 reps was made over 2007-2009 at the Mochełek Experiment Station of the Faculty of Agriculture and Biotechnology, the University of Technology and Life Sciences in Bydgoszcz (Poland). The research investigated traditional (non-self-completing) yellow lupin cultivar, Mister. Triacontanol (TRIA) was applied at two plant development stages: at the beginning of blooming on the main stem and on lateral shoots at three concentrations determined according to literature reports: 0.5 $mg \cdot dm^{-3}$ – low, 1 $mg \cdot dm^{-3}$ – average and 2 $mg \cdot dm^{-3}$ – high. The control involved plants spraying with water at both development stages [3,10].

The experiment was set up after corn grown for silage on the soil of good rye complex, of an average content of phosphorus and high content of potassium and pH – 5.6. In spring there were applied phosphorus – potassium fertilisation at the doses of 80 kg $P_2O_5 \cdot ha^{-1}$ and 100 kg $K_2O \cdot ha^{-1}$ as well as Nitragina for lupin. The Sarfun 65 DS-dressed-seeds were sown in successive research years on April 4, 7 and 8, 3-4 cm deep at the 20 cm row spacing using the Oyord plot drill. The sowing plot area was 16.8 m^2 and the harvest plot area – 13.2 m^2. Directly after sowing Afalon 450 SC was used to control dicotyledonous weeds at the dose of 1.25 $dm^3 \cdot ha^{-1}$, and after plant emergence, at the 3-4 leaf stage – harrowing was performed twice across the rows. In 2007 and in 2009 at the budding phase the plants were sprayed with Sarfun 500 SC against anthracnose.

Spraying with triacontanol followed the experiment design at the beginning of blooming on the main stem (respectively in the research years: on June 9, 12 and 26) and on lateral shoots (in respective research years: on June 19 and 20 as well as July 10) in 400 $dm^3 \cdot ha^{-1}$ of water.

For the control plots the flowers were counted for 20 plants, twice for each plot: at full blooming of the main stem and then on lateral shoots. Prior to harvest from each plot there were randomly sampled 20 each to define the structural yielding components, namely the number of pods and seeds, the seed weight, the seed number and weight per pod as well as the 1000 seed weight. The seed harvest was performed with

Wintersteiger plot combine. For the parameters researched there was made the analysis of variance and the significance of differences was tested with the Tukey test at α = 0.05.

The research period recorded different weather conditions for the yellow lupin plant development and yielding (Table 1). In 2007 and 2009 warm and rainy weather over the vegetative and generative development enhanced abundant blooming and pod setting, while semi-dry conditions at the end of July and at the beginning of August - plant ripening. However, an almost two-fold higher total rainfall, as compared with the multi-year period, in July 2009 prolonged the plant ripening and the period of the vegetation to 145 days. The weather conditions in 2008 were extremely unfavourable to lupin, especially at the initial growth period and then at the generative stage. Starting from the third decade of April to mid July semi-drought and drought occurred; the average total rainfall at that time was much lower than the multi-year mean. Under such conditions lupin plants ripened already after 115 days of vegetation.

Results

A varied weather conditions pattern over the research years affected considerably the generative growth of yellow lupin plants and their yielding. Under favourable moisture conditions in 2007 and 2009 the coefficient of the use of biological potential expressed as the quotient of the number of pods on the harvest day and the number of flowers developed on the main stem was, respectively, 28 and 29%, and in worse conditions, as far as precipitation is concerned, in 2008 – only 20% (Fig. 1). On lateral shoots, its value ranged from 0 in 2008 to 12.3% in 2009 (Fig. 2). Interestingly, the average number of developed flowers did not differ considerably and it was, respectively, on the main stem and lateral shoots in successive research years: 28.5 and 20.2; 26.7 and 11.7 as well as 32.5 and 25.0. However, irrespective of the moisture conditions in all the research years, increasing TRIA doses increased the value of the coefficient of use of the biological potential, especially on the main stem.

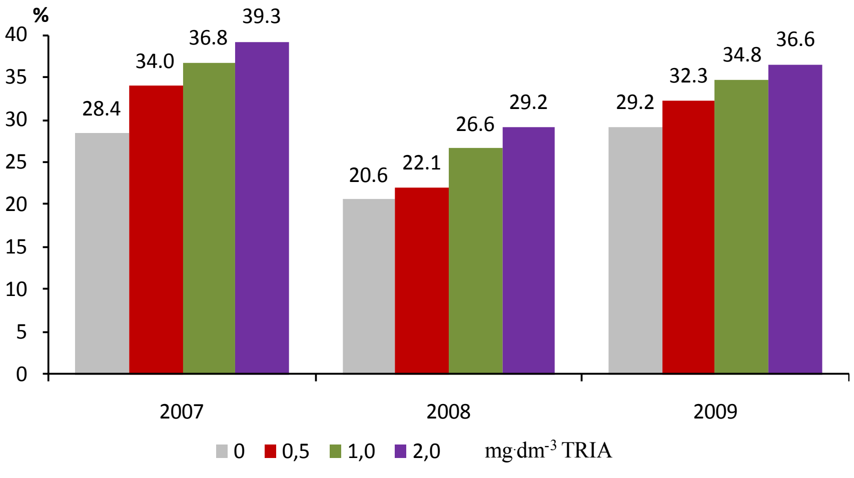

Fig. 1. Effect of TRIA on the biological potential use on main stem in yellow lupin
Rys. 1. Wpływ TRIA na wykorzystanie potencjału biologicznego na pędzie głównym łubinu żółtego

A similar use of the biological potential by lupin plants in 2007 and 2009 resulted in high and almost the same average seed yields (Table 2), and in 2008 the seed yield exceeded 1t·ha^{-1} slightly only. Only in 2007 a later use of TRIA (at the beginning of blooming on lateral shoots) significantly increased the seed yield; in the other two years the date of its application did not differentiate the yellow lupin seed yield significantly. Neither did the triacontanol application date affect the value of structural yield components significantly.

In all the research years after the use of TRIA there occurred an increase in the seed yield (Table 3), however the most favourable and significant effects towards the control were reported in the unfavourable year 2008 after spraying the plants with the bioregulator at the concentration of 2.0 mg·dm^{-3} (41.0% higher seed yield and in 2007 and 2009, 1 and 0.5 mg·dm^{-3} (the seed yield increase, as compared with the control, by 27.2% and 20.5%) were sufficient, respectively.

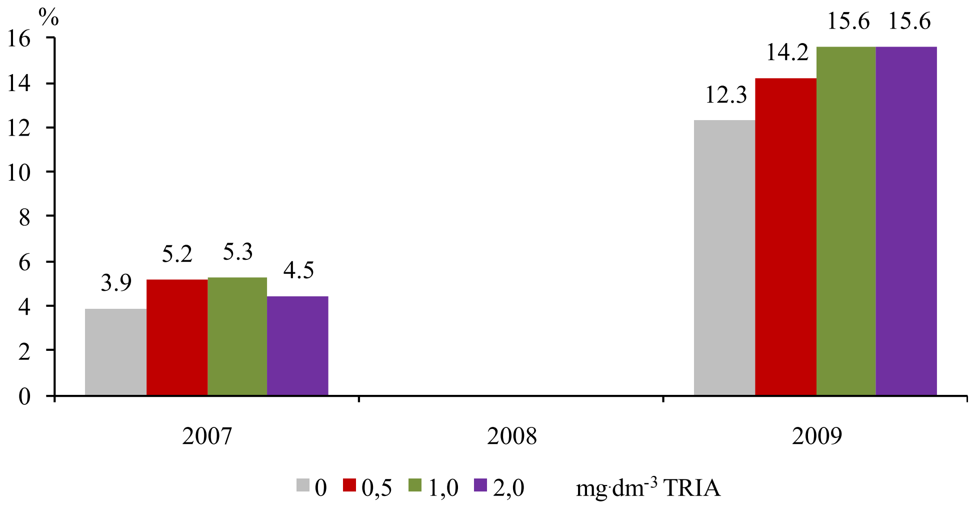

Fig. 2. Effect of TRIA on biological potential use on yellow lupin lateral shoots
Rys. 2. Wpływ TRIA na wykorzystanie potencjału biologicznego na pędach bocznych łubinu żółtego

All the yellow lupin structural yield components investigated in the present research varied a lot as affected by triacontanol. It was found that an increasing TRIA concentration significantly increased the average number of pods per main stem, remaining with no effect on the number on lateral shoots (Fig. 3). For the entire plant the best effect was recorded due to the application of a high concentration which increased the average number of pods, as compared with the control plants, by 31%, while the effect of the application of varied TRIA doses was significantly similar. The number of pods on lateral shoots did not depend significantly on the TRIA dose. The significantly highest number of lupin seeds per main stem was recorded after the application of the highest triacontanol concentration (Fig. 4). The number of seeds on lateral shoots did not depend significantly on the TRIA concentration. The lowest concentration of triacontanol increased significantly, as compared with the control,

Table 1. Mean air temperature and total rainfall according to the Mochełek Experiment Station
Tabela 1. Średnia temperatura powietrza oraz suma opadów według Stacji Badawczej w Mochełku

Specification Wyszczególnienie	Year Rok	Month – Miesiąc IV	V	VI	VII	VIII	IX
Mean air temperature Średnia temperatura powietrza, °C	2007 2008 2009	8.5 7.6 9.8	13.8 13.2 13.2	18.2 17.6 14.5	18.0 19.2 18.6	17.8 17.8 18.2	12,4 12,4 13,7
Mean air temperature over 1949-2009 Średnia temperatura powietrza w latach 1949-2009, °C		7,3	12.8	16.3	18.0	17.4	13.2
Total rainfall, Suma opadów, mm	2007 2008 2009	17.6 38.7 0.4	73.1 11.5 85.3	105.5 15.5 57.4	104.7 58.7 118.0	42.1 95.5 17.6	37,6 20,2 34,4
Mean total rainfall over 1949-2009 Średnia suma opadów w latach 1949-2009, mm		28,0	41.7	53.4	70.8	52.0	41.0

Table 2. Effect of the TRIA application date on yellow lupin seed yield, t.ha-1
Tabela 2. Wpływ terminu zastosowania TRIA na plonowanie łubinu żółtego, t.ha-1

Year Rok	TRIA application date – beginning of blooming Termin zastosowania TRIA – początek kwitnienia kwiatów on the main stem na pędzie głównym	 on lateral shoots na pędach bocznych	Mean Średnia
2007	1.99 B	2.22 A	2.10
2008	1.11 A	1.17 A	1.14
2009	2.11 A	2.0 8 A	2.09
Mean Średnia	1.74	1.82	1.78

Means followed by the same letters did not differ significantly at a = 0.05 acc. to Tukey test
Średnie oznaczone tymi samymi literami nie różniły się istotnie przy a = 0,05 wg testu Tukey'a

the seed weight per plant – by about 15% (Fig. 5), however the effect of the high concentration was also more favourable to the seed weight from lateral shoots. The thousand yellow-lupin seed weight did not vary significantly as a result of the bioregulator concentration and it was, in successive research years, 135, 133 and 134 g.

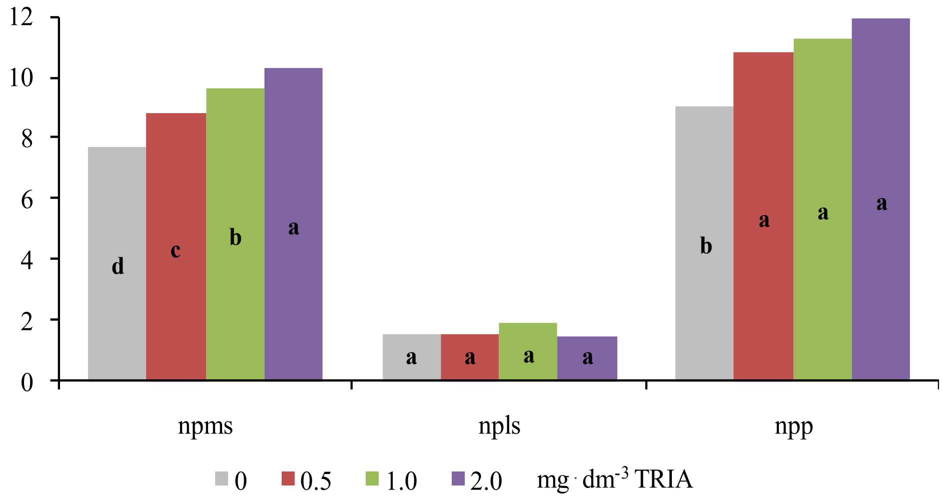

Fig. 3. Effect of TRIA concentration on the number of pods per main stem (npms), lateral shoots (npls) and per plant (npp) in yellow lupin. Means followed by the same letters did not differ significantly at α = 0.05 acc. to Tukey test
Rys. 3. Wpływ stężenia TRIA na liczbę strąków z pędu głównego (npms), pędów bocznych (npls) i z jednej rośliny (npp) łubinu żółtego. Średnie oznaczone tymi samymi literami nie różniły się istotnie przy α = 0,05 wg testu Tukey'a

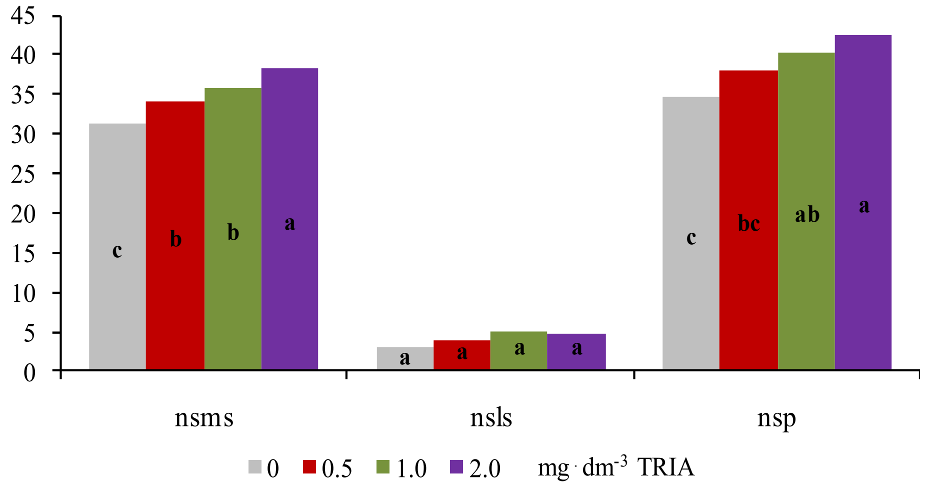

Fig. 4. Effect of TRIA concentration on the number of seeds per main stem (nsms), lateral shoots (nsls) and per plant (nsp) in yellow lupin. Means followed by the same letters did not differ significantly at α = 0.05 acc. to Tukey test
Rys. 4. Wpływ stężenia TRIA na liczbę nasion z pędu głównego (nsms), pędów bocznych (nsls) i jednej rośliny (nsp) łubinu żółtego. Średnie oznaczone tymi samymi literami nie różniły się istotnie przy α = 0,05 wg testu Tukey'a

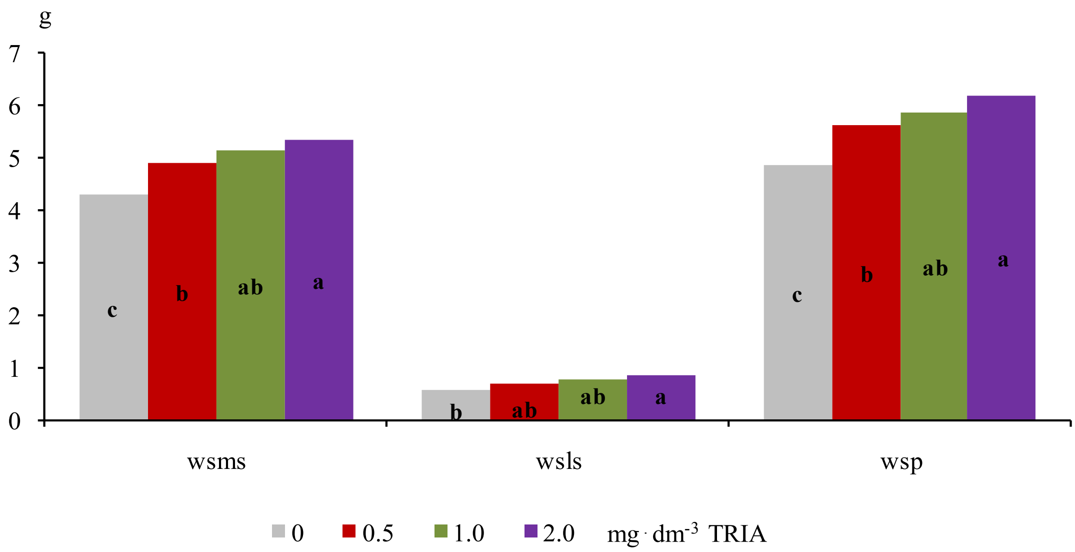

Fig. 5. Effect of TRIA concentration on the weight of seeds per main stem (wsms), lateral shoots (wsls) and per plant (wsp) in yellow lupin. Means followed by the same letters did not differ significantly at α = 0.05 acc. to Tukey test
Rys. 5. Wpływ stężenia TRIA na masę nasion z pędu głównego (wsms), pędów bocznych (wsls) i z jednej rośliny (wsp) łubinu żółtego. Średnie oznaczone tymi samymi literami nie różniły się istotnie przy α = 0,05 wg testu Tukey'a

Table 3. Effect of TRIA concentration on yellow lupin seed yield, $t \cdot ha^{-1}$
Tabela 3. Wpływ stężenia TRIA na plonowanie łubinu żółtego, $t \cdot ha^{-1}$

Year Rok	TRIA concentration – Stężenie TRIA, $mg \cdot dm^3$ 0	0,5	1,0	2,0	Mean Średnia
2007	1.80 b	1.97 b	2.29 a	2.34 a	2.10
2008	0.95 c	1.16 b	1.12 b	1.34 a	1.14
2009	1.85 b	2.23 a	2.17 a	2.11 a	2.09
Mean – Średnia	1.53	1.79	1.86	1.93	1.78

Means followed by the same letters did not differ significantly at = 0.05 acc. to Tukey test
Średnie oznaczone tymi samymi literami nie różniły się istotnie przy a =0,05 wg testu Tykey'a

Discussion

Yellow lupin yielding undergoes greatest fluctuations due to weather conditions, especially the amount of precipitation and its distribution [9]. The total precipitation optimal for lupin in the vegetative period ranges from 350 to 400 mm [17], while the greatest water requirements, besides the seed germination stage, coincide with blooming and pod-setting, and the drought over that period has a very unfavourable effect on the yielding of all the legumes. Under precipitation deficit in 2008 the plants set less pods (no pods on lateral shoots at all), which did not make a full use of the production potential possible and resulted in very low yielding (1.14 $t \cdot ha^{-1}$). The years

2007 and 2009, on the other hand, demonstrated optimal moisture conditions for lupin; hence the seed yields exceeding 2 t·ha^{-1}. From the point of view of seed producers, a high biological potential measured with the number of developed flowers is not used by the yellow lupin plants enough since a considerable part of generative organs (flowers and podsets) shed still before ripening [1,2,12]. According to Byszewski [5], the average number of flowers per yellow lupin plant can reach even 65, while the number of pods on the harvest day rarely exceeds 15 (e.g. 24% of flowers), and the seed yield – 2 t·ha^{-1}. Similarly the results reported by other authors point to a low use of the biological potential of different lupin species [7,16].

In the present research the number of flowers per plant over the research years was strongly differentiated by moisture conditions during vegetation period and ranged from 38.4 to 57.5. However the average value of the coefficient of use of the biological potential on control plants (with no TRIA applied) accounted for 25.6% on the main stem and 5.4% on lateral shoots and was. On average the TRIA doses increased its value up to 32.2% and 6.71%, and this effect was observed in each year of experiment.

The external application of growth regulators can, at least partially, limit lupin flower and podsets shedding [4,14,15]. Once triacontanol was invented, many researchers found its significant effect on the enhancement of yielding of various legume species, e.g. chickpea [18], common bean [4,6], mung bean [10], cowpea [11] and lentil [13]. The results obtained in the present research showed that application of TRIA at all the concentrations significantly increased yellow lupin yielding. Under unfavourable conditions the highest seed yield was obtained following application of 2.0 mg·dm^{-3} TRIA dose, whereas under weather-favourable condition, the low (0.5 mg·dm^{-3}) or medium (1.0 mg·dm^{-3}) dose increased the seed yield significantly as compared to the control. Similarly favourable results of TRIA were reported by Biernbaum et al. [3], however the seed yield increase depended on the TRIA dose and it was cultivar-specific. Varied yield-forming effects, dependent on the concentration of triacontanol, were also reported by Kumaravelu et al. [10] observing a significant increase in the mung bean seed yield after the foliar application of TRIA at the concentration of 0.5 mg·dm^{-3}, however, a significant decrease when 2.0 mg·dm^{-3} TRIA was applied. Significantly best yield-forming effects in growing chickpea [18] and common bean [6] were noted following the application of 4.0 mg·dm^{3} of triacontanol.

In the present research there was also observed a significant increase in the value of structural yielding of plant components – the number of pods and seeds as well as the seed weight per plant after the application of increasing TRIA concentrations. However TRIA doses did not affect values of seed yield elements on lupin branches. The most favourable effects on those characters were recorded after the use of 2 mg·dm^{-3} TRIA, while Kumaravelu et al. [10] noted that 0.5 mg·dm^{-3} TRIA significantly increases the number of pods and seeds per plant as well as the seed weight per pod in mung bean.

Most research into the use of TRIA in growing agricultural and vegetable crops as well as ornamental plants were made in Asia and it is where the regulator is applied at the large production scale [8]. In Poland a number of experiments have been reported into the application of various growth regulators to enhance the use of the production potential by legumes, however, none has been launched in agricultural practise. Exceptionally promising research results into triacontanol in growing yellow lupin for seed definitely call for further experiments, also into other legume species and under various agro-climatic conditions.

Summing up, triacontanol significantly increased yellow lupin yielding, however, the TRIA yield-forming effect mostly depended on the total precipitation and its distribution. Under more favourable moisture conditions the concentration of 0.5-1 $mg \cdot dm^{-3}$ was sufficient and under less favourable – 2 $mg \cdot dm^{-3}$. A higher yellow lupin productivity resulted from a favourable effect of triacontanol on the increase in the value of the coefficient of use of the biological potential of the plants, especially on the main stem. The increasing TRIA concentration also significantly increased the value of structural lupin yielding components, except for the 1000 seed weight. There was found a significant effect of the TRIA application date neither on yellow lupin yielding nor on the structural seed yield components.

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