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RESPONSE OF TIMOTHY (*Phleum pratense* L.) CULTIVARS TO GROWING IN DIVERSIFIED ROW SPACING

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Abstract. In the years 2005-2009 in Szelejewo (Wielkopolskie voivodeship) a field experiment was carried out, aiming at the assessment of response of seed yield and autumn regrowth green forage of three cultivars of timothy: Prosna, Obra and Nowinka to growing in two row spacings: 24 and 36 cm. The research was conducted in two series including the establishment year and two years of production. It was indicated that in the first production year the cultivars Prosna and Obra gave similar yields, whereas in the second year Prosna gave a higher seed yield. The cultivar Nowinka was characterized by the lowest productivity in growing for seeds in both production years. In the first year, the use of row spacing of 24 cm had more favourable effect on forming fertile shoots and seed yield in comparison with row spacing 36 cm. In the second year, seed yield in both row spacings was similar. In the first production year the cultivar Prosna gave the highest yields of autumn regrowth green mass, and Obra the lowest.

Key words: autumn regrowth, field emergence index, generative tillers, seed yield

INTRODUCTION

Apart from the height and quality of green forage yield, seed productivity is one of the most important traits of economic value of the grass cultivars, which determine its market success [Domański 2004]. Cultivars which give a low seed yield are rarely multiplied, in spite of their high fodder value. The ability to reproduce is a genetically determined trait, and differences in seed yields of grass varieties can account for even several dozen percent [Domański 2004]. In the study over timothy, the seed yield of the cultivar giving the lowest yield was by 35% lower than the most fertile one [Martyniak and Domański 1983]. According to Kryzeviciene [2000] and Furuya *et al*. [1989] higher yields of timothy seeds can be obtained in early cultivars. According to Rutkowska and Dębska-Kalinowska [1989], early cultivars of grasses form more fertile shoots in comparison to the late ones. This results from a fast rate of development in the

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establishment year and forming autumn shoots with a larger number of leaves, which has a significant effect on seed yield in the next growing season. Schöberlein [1987] indicated that at a larger number of leaves on autumn shoots the ears of timothy were longer and heavier. Optimal supply of plants in water, nutrients and access to light ensure the use of full ability to form numerous and plump seeds. According to Jokś [1998], a row spacing of 40 cm is recommended in timothy growing for seeds, due to its high light and water requirements, as well as a relatively shallow root system. In field experiments, however, it was proved that a narrow row spacing was better in the first production year [Malko 1983, Jarvi 1992, Szczepanek 2009]. According to Rutkowska *et al*. [1983], an increase in the seed productivity of young grasses in conditions of a smaller row spacing can result from a limited ability to form fertile shoots in the first production year. The canopy structure of timothy depends on the number of plants per area unit and their density in a row. This is determined by the amount of sown seeds, the row spacing, as well as the emergency capacity and survival rate of seedlings in field conditions. Timothy has a low field emergence capacity, which can result from a large sensitivity of husked seeds to environmental factors [Lityński 1987], but also from a strong response to allelopathic compounds released by other grass species during germination [Lipińska 2006]. Too large seed density increases competition and makes emergences difficult, and also reduces the survival rate of seedlings [Kozłowska 1992, Martyniak 2005].

According to the working hypothesis, it was assumed that the height of timothy seed yield depends on genetic traits of the cultivar, which determine the ability to form fertile shoots and seeds, and the response to the size of living space and spacial arrangement of canopy in different row spacings. The aim of this study was to identify and compare reproductive abilities of three cultivars of timothy and to analyse the response of the number of fertile shoots, seed yield and autumn regrowth green forage to growing at different row spacings.

MATERIAL AND METHODS

The study was based on a strict field experiment established at Szelejewo (Wielkopolskie voivodeship) (51°54' N; 17°12' E), in the brown soil with loamy subsoil. Timothy was sown in two series: the first in 2005 and the other in 2007. Two years of production of each series included, respectively 2006-2007 and 2008-2009. The randomized split-plot design was used in three replications. The area of plots was 10 m^2. The cover crop was spring barley sown prior to sowing timothy, in an amount of 80 $kg \cdot ha^{-1}$ and with a row spacing of 12 cm. Timothy was sown between the 20th and 30th of April, across the cover crop rows, in an amount of 4.2 $kg \cdot ha^{-1}$, with row spacings of 24 and 36 cm (factor 1). The tested cultivars were Prosna, Obra and Nowinka (factor 2). The cultivar Prosna was registered in Poland in 2001. It is intended to use for mowing in arable lands. The distinctive feature of this cultivar is high seed yield. It can be grown in the whole area of Poland, in moist soils abundant in nutrients. It is characterized by a good winter hardiness and yielding stability in years [Domański 2005]. The cultivar Obra was registered in Poland in 1985. While using for mowing, it gives high yields of green and dry matter of a good fodder quality. This is a semi-early cultivar. It is characterized by a good winter hardiness and a high yielding stability in years. It can be grown in all the country, in moist soils abundant in nutrients. It is particularly

recommended for growing in field, as well as for permanent grasslands in mixtures [Domański 2005]. The cultivar Nowinka was registered in Poland in 2005. It is intended for mowing, growing in field and in meadow, in the areas with lower rainfalls in the summer. It is an early cultivar, giving good yields in areas with a moderate precipitation, and a particularly high dry matter yield is obtained in the third cut. It can be grown in the whole country, in soils abundant in nutrients. It is recommended for mixtures used on permanent grasslands and for growing in field (www.danko.pl).

Prior to sowing the barley, 80 kg·ha^{-1} N, 42 kg K and 33 kg P was applied. Taking into consideration timothy needs in the years of production, phosphorus and potassium fertilizers in the total rate 31 kg·ha^{-1} P and 87 kg K were applied in autumn, after the harvest of the cover crop (2/3 of the rate) and in the spring (the other part), before the start of growth in the first and second years of seed harvesting. Mineral nitrogen was applied in the summer after the harvest of barley or timothy seeds, in an amount of 50 kg·ha^{-1}, and in spring in the years of production during the start of growth, in an amount of 20 kg·ha^{-1}, and additionally 50 kg·ha^{-1} at the end of April/beginning of May. In the establishment year of the first series of the study in 2005, between the 20th and 30th of May, the field assessment of timothy germination was performed. Seedlings were counted in the row length corresponding to 0.25 m^2. This was the basis for calculating the field emergence index (FEI). In the establishment year of the second series of the experiment (2007) drought in April and at the beginning of May (Table 1) stopped the germination of small timothy seeds, and the assessment of emergences at the beginning of June in strongly tillered barley was impossible.

Table 1. Weather conditions of the experimental site
Tabela 1. Warunki pogodowe w rejonie badań

Miesiąc – Month	Years – Lata					
	1979-2000	2005	2006	2007	2008	2009
	Mean air temperature – Średnia temperatura powietrza, °C					
April – Kwiecień	7.7	9.1	9.3	10.2	8.2	11.5
May – Maj	13.3	13.7	13.7	15.0	13.7	10.1
June – Czerwiec	16.2	16.5	18.3	18.8	18.3	10.4
July – Lipiec	18.4	19.6	23.5	18.7	19.7	19.0
August – Sierpień	18.2	17.4	17.1	18.5	18.6	16.2
September – Wrzesień	13.4	16.0	16.6	13.2	13.4	15.1
October – Październik	8.5	13.2	11.0	8.2	11.3	7.7
	Total precipitation – Suma opadów, mm					
April – Kwiecień	29.4	18.0	35.2	6.2	38.2	16.3
May – Maj	44.3	59.1	40.8	62.8	16.8	77.5
June – Czerwiec	62.0	39.4	19.8	76.4	15.2	155.6
July – Lipiec	80.3	64.6	5.2	87.6	43.0	66.3
August – Sierpień	59.2	59.6	172.3	63.0	56.6	55.0
September – Wrzesień	53.5	14.6	23.2	26.2	18.0	23.0
October – Październik	37.5	0.4	43.4	13.4	3.8	53.0

In the years of production, the earing of the tested cultivars of timothy began after the 10th or the 20th of May. In the middle of June, in the period of flowering, fertile shoots were counted in the row length corresponding to 0.25 m^2. The time of reaching harvesting maturity was different in individual years of the study. In 2006 and 2008 the

harvest was performed between the 20th and 30th of July. In 2007, after the dry April the growth rate and harvest time were speeded up by about two weeks. In 2009 heavy rainfalls in June prolonged the growth, and the harvest of seeds was reaped only on the last days of July. The shoots were cut and sheaved, and threshing was performed after 7-10 days from cutting. Seed yield from the plots, after cleaning and drying up to a moisture of 15%, was the basis for determining the yield per hectare. In the first year of production, the regrowth of green forage was harvested at the beginning of October. In the second year of production, after the harvest of seeds the plantation was eliminated. The obtained results were analysed statistically for the split-plot design, and the significance of differences was determined using Tukey's test, at the significance level P = 0.05.

RESULTS AND DISCUSSION

Germination of timothy in quickly developed barley applied as the cover crop was slow and uneven. During the assessment of emergences, after 30 days from sowing, a part of seedlings was at the initial stage of needling, and some of them had two leaves developed. The actual number of timothy plants after emergences accounted for on mean 25% of the assumed theoretical density (Table 2).

Table 2. Thousand seed weight, plant density, plant number in row and field emergence index in 2005

Tabela 2. Masa tysiąca nasion, obsada roślin, liczba roślin w rzędzie oraz polowy wskaźnik wschodów w 2005 r.

Row spacing Rozstawa rzędów cm	Cultivar Odmiana	TSW MTN g	Plant density Obsada roślin, szt.·m^{-2}		Plant number in row Liczba roślin w rzędzie, szt.·mb^{-1}		Field emergence index FEI %
			theoretical* teoretyczna	real rzeczywista	theoretical* teoretyczna	real rzeczywista	
24	Prosna	0.470	850	244	204	58.6	28.7
	Obra	0.405	990	260	238	62.4	26.3
	Nowinka	0.405	990	284	238	68.2	28.7
36	Prosna	0.470	850	157	306	56.5	18.4
	Obra	0.405	990	261	356	94.0	26.4
	Nowinka	0.405	990	192	356	69.1	19.4
LSD – NIR for – dla:							
plant density – obsady roślin			ns – ni				
field emergence index – PWW			ns – ni				

* for seeding rate 4.2 kg·ha^{-1} and germination capacity 95% – dla ilości wysiewu 4,2 kg·ha^{-1} i zdolności kiełkowania 95%

Emergences were better at a row spacing of 24 cm than of 36 cm (the density 263 and 203 plants·m^{-2}, FEI 27.9 and 21.4%, respectively), but the differences were not statistically significant. Also no differences were proved in germination of the tested cultivars. At the constant seeding rate (4.2 kg·ha^{-1}), the number of seedlings per row should be by 50% higher at a row spacing of 36 cm than of 24 cm. Such an effect was obtained only in the cultivar Obra. The other two cultivars germinated poorly at a row spacing of 36 cm (FEI of 18.4 and 19.4%, respectively), and a number of plants per 1 m of a row was almost identical as at a row spacing of 24 cm. A similar decrease in FEI

along an increase in seed density was indicated in the studies over perennial ryegrass [Martyniak and Martyniak 2002] and red fescue [Martyniak 2005].

In the first year of production, irrespective of the row spacing, the cultivars Prosna and Obra were characterized by a similar seed yield, whereas it was always significantly higher than that of Nowinka (Table 3). Irrespectively of the cultivar, a favourable effect of a row spacing of 24 cm on the seed yield was proved for the second series, as well as for the synthesis of the two series of experiments. The row spacing 24 cm had a favourable effect on productive tillering (Table 4). The number of fertile shoots of timothy in the first and second series of the study and on average from both series was larger at a row spacing of 24 cm in comparison with 36 cm. Similar results were obtained by Malko [1983], who reported that timothy in the first production year had by 57% more fertile shoots at a row spacing of 12.5 cm, as compared with 37 cm. The difference of seed yield in favour of a narrower row spacing was smaller than in the study being the subject of this work and amounted to 10% .

Table 3. Seed yield in the first year of production, Mg·ha^{-1}
Tabela 3. Plon nasion w pierwszym roku użytkowania, Mg·ha^{-1}

Row spacing (R) Rozstawa rzędów cm	Cultivar – Odmiana (V)			
	Prosna	Obra	Nowinka	mean – średnia
	Seria 1 – Series 1			
24	0.680	0.567	0.340	0.529
36	0.660	0.715	0.380	0.585
Mean – Średnia	0.670	0.641	0.360	0.557
LSD – NIR for – dla: R ns – ni V 0.1487 R x V ns – ni				
	Seria 2 – Series 1			
24	0.650	0.606	0.276	0.510
36	0.335	0.277	0.173	0.262
Mean – Średnia	0.492	0.441	0.224	0.386
LSD – NIR for – dla: R 0.0761 V 0.1170 R x V ns – ni				
	Mean for series 1 and 2 – Średnia dla serii 1 i 2			
24	0.665	0.586	0.308	0.520
36	0.497	0.496	0.276	0.423
Mean – Średnia	0.581	0.541	0.292	0.471
LSD – NIR for – dla: R 0.0954 V 0.0587 V/R 0.0830 R/V 0.0922				

ns – ni – non-significant differences – różnice nieistotne

In the present study in the second year of production Prosna gave a higher seed yield than Obra, whereas the early cultivar Nowinka gave the lowest yield, similarly to the first production year (Table 5). Differences were statistically significant in the second series and in the synthesis of two experimental series. Different results were obtained by Kryzeviciene [2000]. They indicate that the yield of an early cultivar of timothy was 3.5 times higher than that of the semi-early and late cultivars. Also Furuya *et al*. [1996]

report that early cultivars are more productive in growing for seeds. Varied assessment of the reproductive abilities of early cultivars of timothy in the present experiment and other studies does not give the grounds for making conclusions concerning seed productivity only on the basis of earing and maturing times.

Table 4. Number of fertile shoots in the first year of production, no·m^{-2}
Tabela 4. Liczba pędów generatywnych w pierwszym roku użytkowania, szt.·m^{-2}

Row spacing (R) Rozstawa rzędów cm	Cultivar – Odmiana (V)			
	Prosna	Obra	Nowinka	mean – średnia
	Seria 1 – Series 1			
24	739	679	648	688
36	487	448	488	474
Mean – Średnia	613	563	568	581
LSD – NIR for – dla: R 166.6 V ns – ni R x V ns – ni				
	Seria 2 – Series 1			
24	739	640	695	691
36	516	536	552	535
Mean – Średnia	627	588	623	613
LSD – NIR for – dla: R 143.8 V ns – ni R x V ns – ni				
	Mean for series 1 and 2 – Średnia dla serii 1 i 2			
24	739	659	671	690
36	501	492	520	504
Mean – Średnia	620	576	596	597
LSD – NIR for – dla: R 91.2 V ns – ni R x V ns – ni				

ns – ni – non-significant differences – różnice nieistotne

In the present study, in the second year of production, the effect of row spacing on seed yield was not proved, and the effect on the number of fertile shoots was relatively poor (Table 5 and 6). Only in the first series an increase in productive tillering of the tested cultivars at a row spacing of 36 cm as compared with 24 cm was indicated. A small effect of the row spacing on the number of ear-bearing shoots and the seed yield of timothy in the second year of production was also indicated by Malko [1983]. Therefore it can be assumed that in conditions of the full tillering the number of seeds per ear and their weight are more important components of yield structure. Similar results are presented by Furuya *et al*. [1996].

Table 5. Seed yield in the second year of production, Mg·ha^{-1}
Tabela 5. Plon nasion w drugim roku użytkowania, Mg·ha^{-1}

Row spacing (R) Rozstawa rzędów cm	Cultivar – Odmiana (V)			
	Prosna	Obra	Nowinka	mean – średnia
	Seria 1 – Series 1			
24	0.457	0.397	0.227	0.360
36	0.453	0.378	0.260	0.364
Mean – Średnia	0.455	0.388	0.243	0.362
LSD – NIR for – dla:				
R ns – ni V 0.0747 R x V ns – ni				
	Seria 2 – Series 1			
24	1.020	0.908	0.499	0.809
36	0.953	0.893	0.429	0.758
Mean – Średnia	0.987	0.901	0.464	0.784
LSD – NIR for – dla:				
R ns – ni V 0.0594 R x V ns – ni				
	Mean for series 1 and 2 – Średnia dla serii 1 i 2			
24	0.739	0.653	0.363	0.585
36	0.703	0.636	0.345	0.561
Mean – Średnia	0.721	0.644	0.354	0.573
LSD – NIR for – dla:				
R ns – ni V 0.0298 R x V ns – ni				

ns – ni – non-significant differences – różnice nieistotne

Table 6. Number of fertile shoots in the second year of production, no·m^{-2}
Tabela 6. Liczba pędów generatywnych w drugim roku użytkowania, szt·m^{-2}

Row spacing (R) Rozstawa rzędów cm	Cultivar – Odmiana (V)			
	Prosna	Obra	Nowinka	mean – średnia
	Seria 1 – Series 1			
24	689	688	697	692
36	896	849	993	913
Mean – Średnia	793	769	845	802
LSD – NIR for – dla:				
R 129.5 V ns – ni R x V ns – ni				
	Seria 2 – Series 1			
24	761	719	837	772
36	740	691	723	718
Mean – Średnia	751	705	780	745
LSD – NIR for – dla:				
R ns – ni V ns – ni R x V ns – ni				
	Mean for series 1 and 2 – Średnia dla serii 1 i 2			
24	725	703	767	732
36	818	770	858	815
Mean – Średnia	772	737	813	774
LSD – NIR for – dla:				
R ns – ni V ns – ni R x V ns – ni				

ns – ni – non-significant differences – różnice nieistotne

The energy of sward regrowth after seed harvesting in the first year of production was high (nearly 9°) and similar in the tested cultivars (data not presented). In 2006 (the first series) heavy rainfalls in August stimulated the growth and yield. In this series of the study, the cultivar Prosna was characterized by the highest yield of autumn regrowth green forage, Nowinka by a moderate yield, and Obra by the lowest (Table 7). In 2008 (the second series), in conditions of moderate rainfalls in August and limited in September, the autumn regrowth yield was law and similar in the tested cultivars. Thus the high tolerance of the cultivar Nowinka to lower total precipitation in summer, given by breeders (www.danko.pl), was not confirmed. Taking into consideration the results of two series of the study, the cultivar Prosna was characterized by the highest yield of autumn regrowth green forage, Nowinka by a significantly lower yield, and Obra by the lowest. Diversification in row spacing had no significant effect on the size of autumn regrowth biomass in the tested cultivars. According to Rogalski and Łyduch [1983], green forage from the autumn regrowth of timothy grown for seeds can be useful in ruminants feeding. The use of autumn regrowth has no effect on the seed yield of this species [Havstad and Aamlid 2002].

Table 7. Green forage yield of autumn regrowth in the first year of production, Mg·ha^{-1}
Tabela 7. Plon zielonej masy odrostu jesiennego w pierwszym roku użytkowania, Mg·ha^{-1}

Row spacing (R) Rozstawa rzędów cm	Cultivar – Odmiana (V)			
	Prosna	Obra	Nowinka	mean – średnia
	Seria 1 – Series 1			
24	9.03	7.83	8.49	8.45
36	8.17	7.61	7.67	7.82
Mean – Średnia	8.60	7.72	8.08	8.13
LSD – NIR for – dla: R ns – ni V 0.703 R x V ns – ni				
	Seria 2 – Series 1			
24	3.19	3.49	2.63	3.11
36	3.33	2.71	3.42	3.15
Mean – Średnia	3.26	3.10	3.03	3.13
LSD – NIR for – dla: R ns – ni V ns – ni R x V ns – ni				
	Mean for series 1 and 2 – Średnia dla serii 1 i 2			
24	6.11	5.66	5.56	5.78
36	5.75	5.16	5.55	5.49
Mean – Średnia	5.93	5.41	5.55	5.63
LSD – NIR for – dla: R ns – ni V 0.454 R x V ns – ni				

ns – ni – non-significant differences – różnice nieistotne

CONCLUSIONS

1. Cultivars of timothy differ in the level of seed yield. In the first production year the cultivars Prosna and Obra give similar yields, whereas in the second year Prosna gives a considerable larger seed yield. The cultivar Nowinka is characterized by the lowest seed yield in the first and second production year.

2. Only in the first year of production a row spacing of 24 cm has a more favourable effect on forming fertile shoots and seed yield of timothy in comparison with a row spacing of 36 cm; in the second year the yield in both row spacing is similar.

3. Heavy rainfalls in August favour regrowth of sward. The cultivar Prosna gives a higher yield of autumn regrowth green forage as compared with the cultivar Obra. A decrease in row spacing from 36 to 24 cm has no significant effect on the autumn regrowth yield of timothy.

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REAKCJA ODMIAN TYMOTKI ŁĄKOWEJ (*Phleum pratense* L.) NA UPRAWĘ W ZRÓŻNICOWANEJ ROZSTAWIE RZĘDÓW

Streszczenie. W latach 2005-2009 w Szelejewie (woj. wielkopolskie) przeprowadzono doświadczenie polowe, którego celem była ocena reakcji plonu nasion i zielonki odrostu jesiennego trzech odmian tymotki łąkowej: Prosny, Obry i Nowinki na uprawę w dwóch rozstawach rzędów: 24 i 36 cm. Badania prowadzono w dwóch seriach obejmujących rok siewu i dwa lata pełnego użytkowania. Wykazano, że w pierwszym roku pełnego użytkowania odmiany Prosna i Obra plonowały podobnie, natomiast w drugim roku większy plon nasion dała Prosna. Najmniejszą wydajnością w uprawie na nasiona w obu latach użytkowania charakteryzowała się odmiana Nowinka. W pierwszym roku zastosowanie rozstawy rzędów 24 cm korzystniej wpływało na wykształcanie pędów generatywnych i plon nasion w porównaniu z rozstawą 36 cm. W drugim roku plon nasion w obu rozstawach rzędów był podobny. W pierwszym roku użytkowania największe plony zielonej masy odrostu jesiennego wydała odmiana Prosna, a najmniejsze Obra.

Słowa kluczowe: odrost jesienny, pędy generatywne, plon nasion, polowy wskaźnik wschodów

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