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EFFECT OF GROWTH DYNAMICS ON SEED PRODUCTIVITY OF FODDER GALEGA (*Galega orientalis* LAM.) BASED ON WRIGHT'S PATH METHOD

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Abstract. This study describes the possibility of practical application of the Wright's path analysis method for assessment of the effect of growth dynamics of fodder galega (*Galega orientalis* Lam.) plants on some seed yield components: shoot length, the length of cluster, the length of productive part of cluster, the number and weight of pods per shoot, the number and weight of seeds and pod weight and thousand seed weight. Weekly increments of plant shoots as affected by hydrothermal conditions were determined to assess growth dynamics. Simple correlation and Wright's path method were applied to assess the effect of growth dynamics on yield components. Applying Wright's path method allowed assessment of the effect of individual plant growth stages on increment at successive stages, which is impossible at using only simple correlations. Growth rate of eastern galega shoots significantly determined the number of pods per productive part of cluster (58.6%), number of pods on the whole length of cluster (48.9%) and the number of pods per shoot (41.5%). Dynamic plant growth in the initial period of development had a positive effect on the assessed seed yield components, whereas plant growth at its final period (beginning of July) had a negative effect. Shoot length increments in June affected the yield structure only to a slight extent.

Keywords: fodder galega, growth dynamics, path analysis, seed yield components

INTROCUDTION

Possibility of forecasting the height of yield obtained in early developmental phases of plants is an essential problem in agriculture. The height of yield is determined by many factors: soil and weather conditions, plant fertilization and varietal traits of grown plants. In the case of perennial plant crops weather conditions play the main role in yield formation, at the fixed soil fertility [Jelinowska 1986, Borowiecki *et al*. 1997]. Under such conditions choosing the time of plant trait measurement is the factor which determines the ability to assess the future yield. Also in breeding work, a possibility of

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early assessment of yield may be the basis for choosing pojedynków, which will meet defined requirements [Jelinowska and Magnuszewska 1961]. Fodder galega (*Galega orientalis* Lam.), grown for 30 years in Baltic states, Canada, France, Russia and Serbia, belong to perennial Fabaceae plants. Growing economic importance of this plant is connected with its early yield, large proportion of leaves in the green matter yield, a high protein content and possibility of use even for 25 years [Møller and Hostrup 1996].

In Poland this plant have only been known for a short time and although its growing for fodder is extremely efficient, the determinants of its seed yield are not sufficiently examined. Large leaf area of fodder galega plants, expressed by the value of leaf area index (LAI) ranging from 12 to 14 causes that plants must strongly compete for solar energy necessary for the process of photosynthesis. Plants growing faster, in defined periods of time, have larger photosynthetic area, assimilate nutrients more efficiently and set seeds better [Wareing and Philips 1985]. Additionally, faster plant growth enables more intensive synthesis of enzymes responsible for cell differentiation and division. Strong competition of galega plant shoots in the canopy, observed in the study by Turkova [2005], leads to forming sterile shoots, and even to complete vanishing of plants. The effect of this is low seed yield, usually caused by a small value of pod setting index. This is expressed by low values of the ratio of the length of cluster productive part to its total length [Ignaczak 2010].

In looking for reasons for a low degree of pod setting it may be useful to apply the assessment of effect of plant growth rate on main traits of yield structure, which can be carried out according to the method of simple correlation, multiple correlation or using the path method. The path analysis method is most often used for the assessment of relationships occurring between the yield height and its structure components [Ivanovic and Rosic 1985, Gravois *et al*. 1991, Okuyama *et al*. 2004] and for the assessment of genotype-environment mutual relationships [De Sousa-Vieira and Milligan 1999]. It is also applied for the evaluation of complex structures, when a multitude of relations makes it possible to use classic methods [Kozak and Kang 2006]. This is of particular importance in plant breeding with selection and creating new varieties [Li 1956, Chang and Milligan 1992, Diz *et al*. 1994]. The chosen statistical method allows the assessment of force linking correlations between the growth rate of plants and yield structure traits in mutually related systems, also taking into account both the effect of individual growth phases on those following one another and a dependence of later phases on earlier developmental stages of the plant [Kozak and Kang 2006].

In this study, which was focused on methodology, an attempt was made to apply Wright's paths to assess the effect of growth rate of fodder galega (*Galega orientalis* Lam.) on the structure and height of seed yield.

MATERIAL AND METHODS

The study was carried out in 2001-2003 on a seed plantation of fodder galega established in 1997 in the area of the experimental station of the Podlasie Academy in Siedlce (52º10' N; 22º17' E). Seeds of the fodder galega cultivar Gale after inoculating with bacteria *Rhizobium galegae* were sown in soil classified as the hortisol type with pH = 6.9 and with a high content of humus, nitrogen, available potassium magnesium and phosphorus as well as microelements [Deska 2009].

Averages used in this work were obtained in the years of the study, since the statistical analysis of the results did not show a significant effect of hydrothermal conditions of growing seasons on the dynamics of plant development. Plant growth period in the studied years was characterized by a low precipitation in the months of plant growth as compared with the long-term period, but from the 20th to 30th April precipitation almost two times exceeded the long-term average (Fig. 1). Total precipitations higher than that for long-term period were also observed between 20th and 31st May, between 10th and 20th June and in the first half of July. Such precipitation distribution did not pose a higher threat to plant yield. Average air temperatures at that time were slightly higher than the long-term means. The beginning of May and the time between 1st to 20th July were warmer (on average by 5°C). Plant growth under such conditions proceeded without larger delay as compared with other growing years.

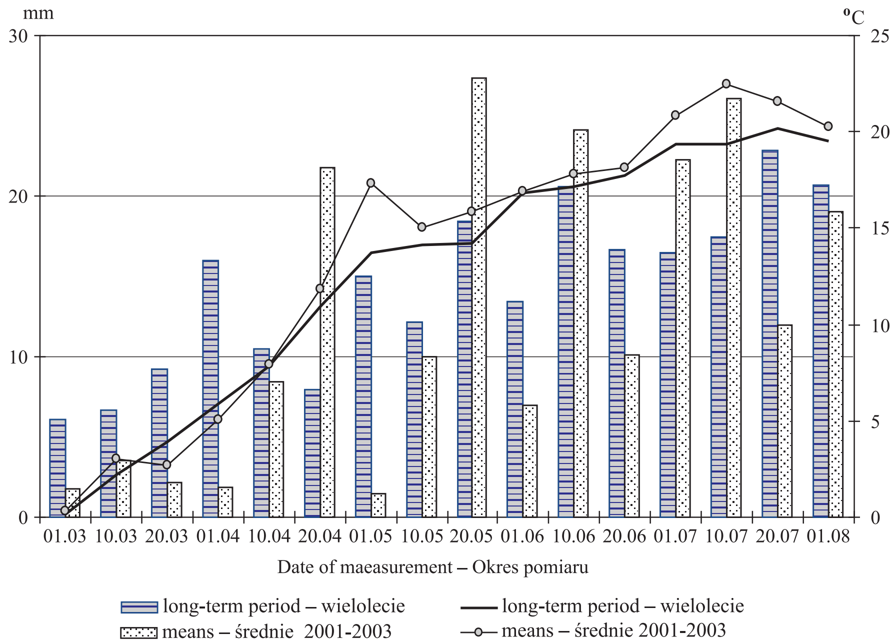
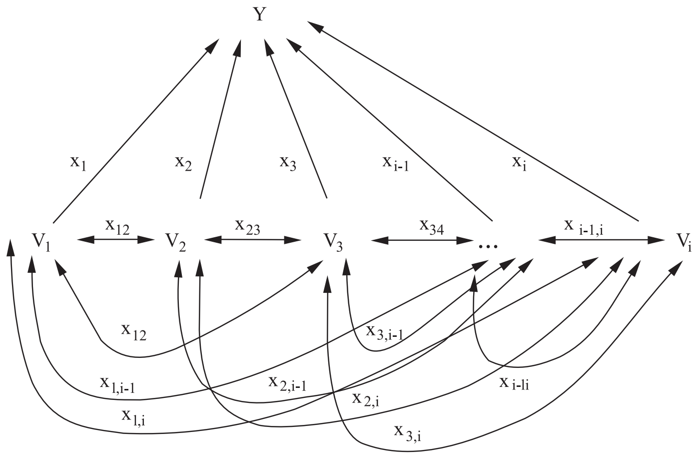


Fig. 1. Precipitation and air temperature in the investigation period – means for years
Rys. 1. Opady i temperatury w okresie badań – średnie dla lat

In the early spring (from 20th to 31st March) 30 rosettes of plant shoots were randomly chosen, growing in the central parts of each of 6 randomly selected plots. Measurements of shoot length increment were carried out at 7-day intervals, from the moment of starting the shoot elongation until the end of plant growth. Shoot length increment was calculated as a difference of the shoot length in successive measurements.

During the growing period a part of plant shoots died, not forming pods. Plants forming fruits were harvested in the phase of pod full maturity. After drying the plants, the selected traits were measured: shoot length, cluster length, the length of productive part of cluster, the number and weight of pods per shoot, the amount and weight of seeds and the average weight of one pod and thousand seed weight (TSW). The length of productive part of cluster was determined as a distance between the first and last pod of the main cluster. Characteristic of variability of the studied traits was assessed determining the basic parameters of distribution of studied seed yield component values.

Obtained results were statistically worked out using the simple correlation method, as well as the Wright's path method. Using the path method enabled the analysis of plant development effect in a cause and effect system. Successive plant developmental phases have an effect on its development in the next phases, being at the some time the result of the previous developmental phases. As a result, a system of relationships is created, whose statistical interpretation was presented in Figure 2.



V_1, V_2, .., V_i – values of shoot length gains in successive periods – wartości przyrostu długości pędu roślin w kolejnych terminach
x_1, x_2, .., x_i – interactions between growth rate and yield components – oddziaływania szybkości wzrostu na komponenty plonu
x_{12}, x_{23}, x_{34}, .., $x_{i-1,i}$ – interactions between growth rate in successive stages of plant development – oddziaływania pomiędzy szybkością wzrostu w kolejnych fazach rozwoju roślin
Y – value of measured trait – wartość mierzonej cechy

Fig. 2. Dependence scheme of path analysis applied in the study
Rys. 2. Schemat zależności analizy ścieżkowej zastosowanej w eksperymencie

At the assumed system, the path analysis was carried out according to Chrobak and Payne [1995], calculating the direct effect, as the direct effect of the studied factor (date of measuring the shoot length increment) on the analysed trait and an indirect effect (e.p.), as an indirect factor explained by each of the other factors. Also regression coefficients were calculated and an algorithm determining the effect of plant growth on value of measured qualitative traits of fodder galega seed yield components was written [Draper and Smith 1973].

RESULTS AND DISCUSSION

Measurements of plant (shoot) length increments were begun in the early spring period. At first, until 7th April, the plants formed a leaf rosette, without a distinct increment of shoot length. First plant increments (23.8% of the studied sample) were observed at the date 7-14.04 (Fig. 3).

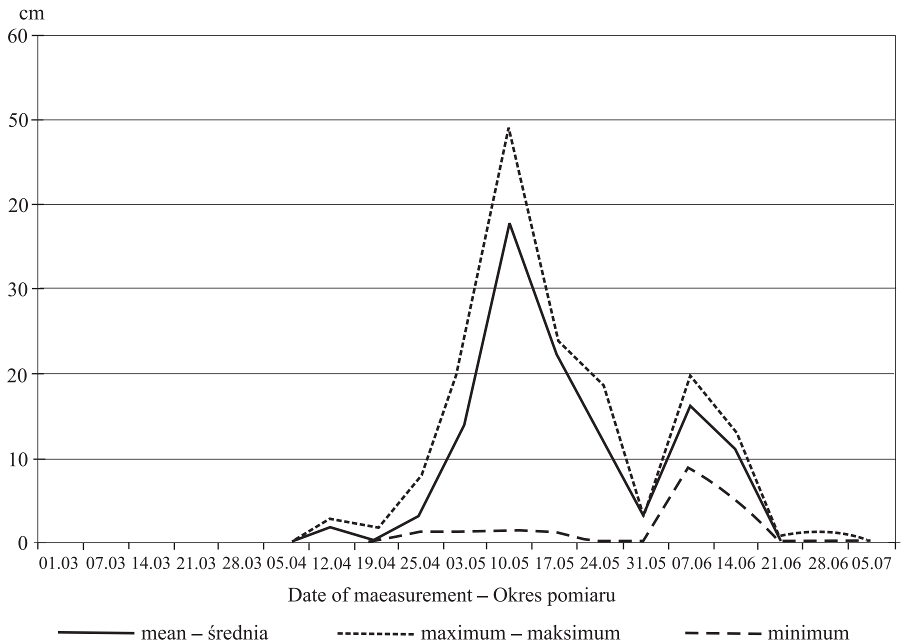


Fig. 3. Dynamics of shoot length increment
Rys. 3. Dynamika przyrostu długości pędów

Most plants (82.8%) began forming shoots within the period 14-21.04, and until 28.04 all the rosettes were transformed into shoots. The largest increments of shoot length for most plants were found at the date 5-12.05, and the average weekly increment at that time amounted to 37 cm. In that period a certain number of plant shoots (16.7%) stopped elongation and after 12.05 a distinct division into groups with different increment of shoots was observed in the studied sample of plants. The majority of plants formed inflorescences and came into the flowering phase, which lasted until 23.05. At the same time, weekly increments of shoot length started to decrease considerably. Another period of increment occurred at the date 02-06.06, when the plants formed infructescences. A group of shoots (34) was distinguished at that time which showed weekly increments up to 20 cm. After that period only few plants showed a small increment of shoot length. Part of the studied sample of galega shoots (43.3%) died without forming inflorescences. Similar effects were observed by Turkova [2005].

Variation analysis of the studied yield components (Table 1) for the described sample of galega plants indicated large differences in values of the studied parameters of plants. Ranges of values of the studied traits in the case of the number of pods and seeds deriving from one shoot, staying in the range 4.0-52.0 and 9.0-122.0 respectively, proves a small stability of traits of the studied plant population. Average weight of one pod (V = 85.9%), pod weight per shoot (V = 79.8%) and the weight of seeds obtained from one shoot (V = 78.8%) were characterized by the largest coefficients of variations. Thousand seed weight (V = 36.0%) and the cluster length (V = 39.5%) were characterized by the smallest variation. The high range of values of the studied traits gives a possibility of making selection towards extreme values the breeders are interested in, which was applied at creating commercial cultivars of fodder galega [Baležentienė and Spruogis 2002].

Table 1. Selected parameters of described plant population
Tabela 1. Wybrane parametry opisywanej populacji roślin

Number Numer	Trait – Cecha	Average Średnia	Minimum	Maximum	V %
1	Length of cluster Długość grona	13.4	4.0	30.0	39.5
2	Length of productive part of cluster Długość produktywnej części grona	9.2	2.0	23.0	48.9
3	Number of pods per shoot Liczba strąków na pędzie	14.7	4.0	52.0	74.1
4	Pod weight per shoot Masa strąków na pędzie	1.54	0.21	4.73	79.8
5	Average number of seeds per pod Średnia liczba nasion w strąku	4.43	1.00	7.00	40.6
6	Number of seeds per shoot Liczba nasion na pędzie	50.5	9.0	122.0	66.7
7	Seed weight per shoot Masa nasion na pędzie	1.04	0.10	2.90	78.8
8	Average pod weight Średnia masa strąka	0.507	0.104	1.824	85.9
9	Thousand seed weight Masa tysiąca nasion	18.9	7.8	32.2	36.0

Analysis of mutual relationships between increments of shoot length in successive dates of measurements indicated the presence of significant relationships for many measuring periods (Table 2).

Table 2. Correlation coefficients between the successive phases of plant increment
Tabela 2. Współczynniki korelacji pomiędzy kolejnymi fazami przyrostu roślin

Time of measurement Okres pomiarów	29.06- -05.07	22.06- -28.06	15.06- -21.06	08.06- -14.04	01.06- -07.06	25.05- -31.05	18.05- -24.05	11.05- -17.05	04.05- -10.05	27.04- -03.05	20.04- -26.04
13.04-19.04	0.150	-0.294*	-0.114	0.064	0.084	-0.123	-0.070	-0.221*	-0.132	0.162	-0.001
20.04-26.04	-0.153	0.240*	0.090	-0.222*	-0.132	0.210*	-0.001	0.034	0.308*	0.464*	
27.04-03.05	-0.022	-0.100	-0.241*	-0.115	0.010	0.314*	0.023	0.230*	0.312*		
04.05-10.05	-0.265*	-0.113	0.015	0.109	0.191	0.283*	0.292*	0.354*			
11.05-17.05	-0.301*	-0.253*	-0.303*	0.014	0.144	0.539*	0.657*				
18.05-24.05	-0.214*	-0.412*	-0.194	0.253*	0.304*	0.404*					
25.05-31.05	-0.290*	0.024	-0.204*	0.055	0.049						
01.06-07.06	-0.293*	-0.352*	-0.114	-0.001							
08.06-14.06	-0.254*	-0.320*	0.035								
15.06-21.06	0.502*	0.540*									
22.06-28.06	0.531*										

* significant correlation coefficients at $P \leq 0.05$ – współczynniki korelacji istotne przy $P \leq 0,05$

Until the half of the measuring period (18.05) plant shoot length increments had a significant effect on the plant length increment in the next measurement period. The highest amount of significant correlation coefficients was found for the increment at the four middle dates of measurement: 11.05,17.05, 24.05,31.05 and at the last three: 22.06, 28.06, 05.07. This was the period when the average air temperature was above 12°C. For the last week of measurements 22.06-05.07 it was found that plant shoot length increments at that date depended significantly on increments at the beginning of the plant growth.

High increments of galega plant shoot length in individual dates of plant growth had a varied effect on values of individual yield structure components (Table 3), which is indicated by the signs and values of calculated correlation coefficients. The fast initial rate of plant growth had a significant, positive effect on values of the total length (r = 0.382) and the length of productive part of cluster (r = 0.413) and of the number of pods per shoot (r = 0.261). High increment of plant length in successive 5 weeks decreased significantly the number of pods on shoots (r = –0.312, r = –0.223, r = –0.390, r = –0.262, r = –0.383). The values of pod weight were significantly affected by the plant growth in the period from 18 to 24.05. Average number of seeds per pod was positively affected by a high dynamics of plant growth in the period 20.04–10.05 (r = 0.341, r = 0.260, r = 0.211), and negatively affected by the plant growth from 15 to 28.06 (r = –0.205, r = –0.314). Weight of galega seeds obtained from one shoot was positively affected by a high plant increment from 1st to 10th and from 20th to 31st May (r = 0.205, r = 0.223). The weight of one pod was significantly limited by the increment of shoot length at the date 25-31.05 (r = –0.234) and increased in the periods 15-21.06 (r = 0.225) and 29.06--05.07 (r = 0.204). An increase in thousand seed weight was positively affected by a high increment of shoot length in the period from 11 to 31.05 (r = 0.254, r = 0.204, r = 0.232). Values of yield traits were most affected by the plant growth at the date 04-10.05, that is the period of the largest increments of shoot length for the majority of plants in the studied sample. Plants growing at that time had a significantly higher number of seeds per pod (r = 0.211) and the number and weight of seeds per shoot (r = 0.232, r = 0.205), but smaller lengths of cluster (r = –0.265), its productive part (r = –0.283) and a smaller number of pods per shoot (r = –0.390).

The simple correlation coefficients obtained are characterized by low values, and additionally, they do not take into consideration the fact of the effect of individual dates of galega shoot growth on their increment in successive developmental phases. Using Wright's path method for calculations enables obtaining a more fitted model of the effect of growth phases on yield-forming components. Analysing the plant growth rate during the growing period (Fig. 2), 2 periods of intensive plant growth may be observed. The first period, connected mainly with the vegetative development of the plant main shoot, lasts from 26.04 to 03.06. The beginning of formation of plant generative organs resulted in the inhibition of plant increment, but the beginning of flowering determined a long period of shoot elongation, connected with the elongation of flowering cluster.

Table 3. Effect of plant increment stages on productive traits in fodder galega
Tabela 3. Wpływ faz przyrostu roślin na cechy produkcyjne roślin rutwicy wschodniej

Trait Cecha	Time of measurement – Okres pomiaru											
	13.04-19.04	20.04-26.04	27.04-03.05	04.05-10.05	11.05-17.05	18.05-24.05	25.05-31.05	01.06-07.06	08.06-14.04	15.06-21.06	22.06-28.06	29.06-05.07
1	0.382*	0.025	0.062	-0.265*	-0,084	-0,074	0,034	-0,114	-0.034	-0.182	-0.092	-0.101
2	0.413*	0.034	0.095	-0.283*	-0.139	-0.162	-0.020	-0.124	-0.014	-0.114	-0.031	-0.050
3	0.261*	-0.312*	-0.223*	-0.390*	-0.262*	-0.383*	-0.173	-0.070	0.082	0.073	0.011	-0.063
4	-0.023	0.074	-0.024	0.182	0.134	0.214*	-0.154	0.082	0.073	0.091	-0.060	0.132
5	0.193	0.341*	0.260*	0.211*	0.131	0.182	0.060	-0.124	-0.130	-0.205*	-0.314*	-0.111
6	0.041	0.073	0.114	0.232*	0.063	0.151	-0.232*	0.043	0.024	0.011	-0.033	0.214*
7	0.020	0.042	0.012	0.205*	0.154	0.223*	-0.114	0.094	0.071	0.023	-0.120	0.092
8	-0.093	0.115	-0.082	0.151	0.073	0.174	-0.234*	0.061	0.053	0.225*	0.052	0.204*
9	0.000	0.071	0.071	0.014	0.254*	0.204*	0.232*	0.053	0.050	-0.140	-0.164	-0.071

* significant correlation coefficients at $P \leq 0.05$ – współczynniki korelacji istotne przy $P \leq 0{,}05$
1, 2, …, 9 – investigated traits as in Table 1 – oznaczenia cech jak w tabeli 1

The total length of cluster and the length of its productive part are determined by the course of plant development at 3 growing dates (Table 4). Strong plant development from 10th to 20th April (direct effects of traits equal to: 0.374 and 0.406, respectively) has a favourable effect on forming long inflorescences. Intensive increments of the aboveground part of plants in the first half of May and the first ten days of July had a negative effect on the length of formed inflorescences (direct effects amounted to, respectively, –0.269 and –0.221 for the length of cluster and –0.275 and –0.184 for the length of productive part of cluster). Indirect effects of the studied dates are small and in complex paths they neutralize their effect. For this reason, phenotypic correlation coefficients are very similar to the direct impact coefficients.

Table 4. Direct and indirect effects of growth dynamics on selected parameters of cluster structure
Tabela 4. Efekty pośrednie i bezpośrednie wpływu dynamiki wzrostu na wybrane parametry struktury grona

Length of cluster– Długość grona							
Date Termin	19.04	10.05	07.07				Correlation coefficient Współczynnik korelacji
9.04	**0.374**[1]	0.035[2]	-0.033				0.382
10.05	-0.049	**-0.269**	0.056				-0.264
07.07	0.057	0.069	**-0.221**				-0.103
Length of productive part of cluster – Długość produktywnej części grona							
Date Termin	19.04	10.05	05.07				
9.04	**0.406**	0.036	-0.028				0.410
10.05	-0.053	**-0.275**	**-0.047**				-0.283
05.07	0.061	0.070	-0.184				-0.051
Number of pods per shoot – Liczba strąków na pędzie							
Date Termin	19.04	26.04	10.05	24.05	21.06	05.07	
19.04	**0.259**	0.000	0.037	0.021	-0.032	-0.065	0.262
26.04	0.000	**-0.309**	-0.087	0.000	0.026	0.065	-0.314
10.05	-0.039	-0.096	**-0.283**	**-0.091**	0.003	0.110	-0.391
24.05	-0.020	0.000	-0.081	-0.318	-0.054	0.090	-0.380
21.06	-0.033	-0.028	0.000	0.059	**0.292**	-0.214	0.072
05.07	0.045	0.046	0.072	0.067	0.145	**-0.431**	-0.062

[1] bold – direct effect – pogrubione – efekt bezpośredni
[2] indirect effect – efekt pośredni

Multiple regression equation, describing the effect of plant growth rate in individual dates on the number of pods set on the shoot, involves changes observed at the following dates: 19.04, 26.04, 10.05, 24.05, 21.06, 05.07. Dynamic plant growth at the end of April and in May had a negative effect on setting pods (direct effects, Table 4). Vegetative growth of plants in the middle of April had a favourable effect on setting pods on the shoot (e.b. = 0.259), and the plant growth rate at that date was not connected with the plant development at other studied dates. Also growth after the 20th of June had a positive effect on the value of this trait (e.b. = 0.292). Continuation of plant growing in July had a negative effect on the value of the studied trait, mainly through total indirect effects, resulting from a relation between plant vegetative growth rate on the first days of July and the period preceding this time.

The multiple regression equation took into consideration 4 dates affecting the number of seeds per pod: 26.04, 07.06, 28.06, 05.07 (Table 5). The number of seeds per pod was a trait strongly determined by the plant growth dynamics between 20th and 30th of June. Plant height increment in this period strongly inhibited forming seeds in pods. Plant increments in this period are connected with increments from 20th and 30th April (indirect effect = 0.124), from 1st to 10th June (e.p.= –0.067) and from 1st to 10th July (e.p. = 0.126). Sum of indirect effects gives the summary negative direct effect (e.b. = –0.627), stronger in comparison with the genotypic correlation coefficient (r = –0.314).

Table 5. Direct and indirect effects of growth dynamics on selected parameters of seed yield structure in fodder galega
Tabela 5. Efekty pośrednie i bezpośrednie wpływu dynamiki wzrostu na wybrane parametry struktury plonu nasion

Average number of seeds per pod – Średnia liczba nasion w strąku					
Date Termin	26.04	07.06	28.06	05.07	Correlation coefficient Współczynnik korelacji
26.04	**0.505**	0.027	-0.153	-0.036	0.340
07.06	-0.067	**-0.202**	0.221	-0.069	-0.121
28.06	0.124	0.071	**-0.627**	0.126	-0.314
05.07	-0.076	0.059	-0.332	**0.238**	-0.110
Number of seeds per shoot – Liczba nasion na pędzie					
Date Termin	10.05	24.05	24.05	05.07	
10.05	**0.323**	0.072	-0.100	-0.061	0.232
24.05	0.092	**0.254**	-0.142	-0.050	0.153
31.05	0.091	0.102	**-0.356**	-0.069	-0.234
05.07	-0.082	-0.053	0.102	**0.239**	0.210
Average pod weight – Średnia masa strąka					
Date Termin	24.05	31.05	21.06		
24.05	**0.344**	-0.130	-0.041		0.173
31.05	0.138	**-0.324**	-0.043		-0.232
21.06	-0.064	0.064	**0.219**		0.224

denotations as in Table 4 – oznaczenia jak w tabeli 4

Plant growth rate between 20th and 30th April (e.b. = 0.505) (Table 5) had a positive effect on the number of seeds formed in the pod, it was connected with inhibition of plant growth in June and July (Table 2), which is shown by coefficients of indirect effects. Variability of the number of seeds per shoot was determined in 21.5%, by the growth rate at 4 growing dates (Table 6). Plant growth from 1st to 10th and from 10th to 20th May had a positive effect on seed formation (e.b. = 0.323 and 0.254). Inhibiting seed formation was connected with plant vegetative development from 20th to 30th of May, since the plants showing a higher growth rate in this period formed less seeds (e.b. = –0.356). Plant height increment from 20th to 30th June was connected with a larger amount of seeds formed by the plant (e.b. = 0.239).

Table 6. The parameters of regression equations of the effect of growth dynamics on selected parameters of seed yield structure
Tabela 6. Parametry równań regresji wpływu dynamiki wzrostu na wybrane parametry struktury plonu nasion

Cecha Trait	Wyraz wolny Free term	Periods of shoot length increment – Okres przyrostu długości pędu										
		13.04-19.04	20.04-26.04	04.05-10.05	11.05-17.05	18.05-24.05	25.05-31.05	01.06-07.06	15.06-21.06	22.06-28.06	29.06-07.07	Determination coefficient Współczynnik determinacji %
1	16.1	3.47	–	-0.57	–	–	–	–	–	–	-1.29	20.9
2	11.3	3.19	–	-0.10	–	–	–	–	–	–	-0.91	23.3
3	31.7	5.66	-1.62	-0.22	–	-0.46	–	–	2.61	–	-5.19	41.5
4	–	–	–	–	–	–	–	–	–	–	–	–
5	4.3	–	0.31	–	–	–	–	-0.031	–	-0.83	0.34	33.7
6	26.4	–	–	0.77	–	1.13	-7.10	–	–	–	8.85	21.5
7	–	–	–	–	–	–	–	–	–	–	–	–
8	0.5	–	–	–	–	0.02	-0.08	–	0.08	–	–	15.8
9	15.0	–	–	–	0.17	–	–	–	–	–	–	5.3

1, 2, ..., 9 – investigated traits as in Table 1 – oznaczenia cech jak w tabeli 1

Average weight of one pod was determined in 15.8% (Table 6) by the plant growth dynamics at 3 growing dates. Intensively growing plants until 24 May were characterized by a higher weight of pods (e.b = 0.344). Further intensive growth of plants until 31 May had an unfavourable effect on the pod weight (e.b. = –0.324). Plants whose shoots elongated intensively until 24 May, continued intensive length increment also in the next measuring period, hence e. p. = 0.138, increasing the negative effect of plant growth rate on this trait at the end of May, in comparison with the correlation coefficient value (r = –0.232). Plant growth between 10th and 20th June positively affected the average pod weight (e.b. = 0.219).

The calculated regression coefficients (Table 6) allowed creation of the algorithm determining the effect of plant growth on value of the measured qualitative traits of fodder galega seed yield components. Plant vigour, expressed by their growth rate, had various effect on diversification of traits of seed yield component. In this study the lack of a significant relationship between the number of seeds per shoot and the plant growth rate was observed.

The statistical analysis allowed determination of relationships between plant growth rate during the growing period, as well as the effect of individual growth stages on changes in some yield-forming traits. Applying the path method enabled determination of valued of partial coefficients, determining the actual effect of individual growth stages on the values of described yield-forming components of fodder galega. This was possible by taking into consideration indirect effects of the plant state at individual stages of their growth. Plant traits connected with their height (the amount and assimilating area of leaves, domination of a plant over other plants of the canopy etc.) in individual growth phases, affect the rate of development of their morphological parts in the successive, following developmental stages [Wareing and Phillips 1981]. Intensity of physiological processes and their direction in individual developmental phases determine the plant yield, which was found in the studies of other species of field crops [Jelinowska and Magnuszewska 1961, Milthorpe and Moorby 1974].

The conducted study allowed determination of a regression equation describing the effect of growth dynamics at individual developmental stages, on fodder galega seed yield components. To determine successive approximations of the equation notation, it is necessary to conduct long-term observations, which will allow a precise determination of variability in the years.

CONCLUSIONS

1. Growing fodder galega for seed was characterized by a large variability in yield structure components. This referred mainly to the number and weight of pods per shoot and the number and weight of seeds formed per shoot.

2. Dynamic growth of plants at the initial developmental stage positively affected the assessed seed yield components, whereas plant growth at the final stage (beginning of July) had a negative effect. Shoot increments in June had only a slight effect on seed yield components.

3. Increment rate of fodder galega plant shoot length has the largest effect on the number of pods per the productive part of cluster (58.6%), the number of pods per cluster (48,9%) and the number of pod per shoot (41.5%).

4. Applying Wright's path method enabled assessment of the effect of fodder galega plant growth rate in individual phases on their increment in successive phases. Using this method makes it possible to make more precise description of plant development model than that made only with the use of simple correlations.

5. Determining more precise values of regression equation coefficients describing effect of plant growth dynamics on seed yield components requires further research taking into consideration changes in hydrothermal conditions with larger time range.

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OCENA WPŁYWU DYNAMIKI WZROSTU NA PRODUKTYWNOŚĆ NASIENNĄ RUTWICY WSCHODNIEJ (*Galega orientalis* LAM.) W OPARCIU O ŚCIEŻKI WRIGHTA

Streszczenie. W pracy opisano możliwość praktycznego zastosowania metody analizy ścieżek Wrighta do oceny wpływu dynamiki wzrostu roślin rutwicy wschodniej (*Galega orientalis* Lam.) na wybrane komponenty plonu nasion: długość pędów, długość grona oraz produktywnej części grona, liczbę i masę strąków na pędzie, liczbę i masę nasion oraz masę strąków i masę tysiąca nasion. Przy ocenie dynamiki wzrostu określono tygodniowe przyrosty pędów roślin na tle warunków hydrotermicznych. Do oceny wpływu dynamiki wzrostu na komponenty plonu zastosowano korelację prostą i metodę ścieżek Wrighta. Zastosowanie metody ścieżek Wrighta umożliwiało ocenę wpływu poszczególnych faz wzrostu roślin na wzrost w kolejnych fazach, co jest niemożliwe przy zastosowaniu wyłącznie prostych korelacji. Tempo wzrostu pędów rutwicy wschodniej istotnie determinowało obsadę strąków na produktywnej części grona (58,6%), obsadę strąków na całkowitej długości grona (48,9%) oraz liczbę strąków na pędzie (41,5%). Na oceniane komponenty plonu nasion pozytywnie wpływał dynamiczny wzrost roślin w początkowym okresie rozwoju, natomiast wzrost roślin w jego końcowym okresie (początek lipca) oddziaływał negatywnie. Przyrosty długości pędów w czerwcu wpływały na strukturę plonu jedynie w nieznacznym stopniu.

Słowa kluczowe: analiza ścieżkowa, dynamika wzrostu, komponenty plonu nasion, rutwica wschodnia

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