VARIABILITY OF LENGTH OF STEM OF DETERMINATE AND INDETERMINATE CULTIVARS OF COMMON VETCH (VICIA SATIVA L. SSP. SATIVA) AND ITS IMPACT ON SELECTED CROPPING FEATURES

ZMIENNOŚĆ DŁUGOŚCI ŁODYG ODMIAN WYKI SIEWNEJ (VICIA SATIVA L. SSP. SATIVA) O ZDETERMINOWANYM I NIEZDETERMINOWANYM WZROŚCIE I ICH WPŁYW NA NIEKTÓRE CECHY UŻYTKOWE

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ABSTRACT

In the years 2001 and 2002, the study was conducted in six experiments in order to examine the conditioning of the length of stem variability and its impact on cropping features of determinate and indeterminate cultivars of common vetch. Rainfall in June and July as well as during the whole growing season was positively correlated with length of stem, but negatively correlated with seed yield, to a larger extent in the group of indeterminate cultivars than in the determinate one. Duration of blooming stage, length of stem, and seed yield showed the largest variability in both groups. Increase in length of stem of plants of indeterminate cultivars led to the delay in maturation, to less even maturation, and to the decrease in the thousand seed weight and seed yield. Increase in length of stem of plants of determinate cultivars delayed reaching the phase of technical maturation and decreased evenness of plant maturation. Determinate growth of common vetch did not lead to the reduction of lodging.

KEY WORDS: common vetch, determinate cultivars, length of stem, lodging

DETAILED ABSTRACT

W sześciu Stacjach Oceny Odmian, należących do Centralnego Ośrodka Badania Odmian Roślin Uprawnych, badano w latach 2001 i 2002 wpływ warunków pogodowych na zmienność długości łodyg czterech odmian wyki siewnej o niezdeterminowanym (tradycyjnych) oraz jednej odmiany i jednego rodu hodowlanego o zdeterminowanym typie wzrostu (samokończących). Celem pracy było określenie zakresu zależności pomiędzy warunkami pogodowymi w okresie wegetacji a długością łodyg oraz porównanie związku pomiędzy długością łodyg a czasem trwania poszczególnych faz rozwojowych, wyleganiem, masą tysiąca nasion i plonami nasion odmian wyki o niezdeterminowanym i zdeterminowanym wzroście. Przebieg pogody w latach badań był odmienny - w 2001 roku suma opadów w okresie wegetacji wyki była średnio o 111.4 mm wyższa, a średnie dobowe temperatury o 0.8 ^{o}C niższe w porównaniu z 2002 rokiem. Długość łodyg odmian samokończących była średnio o 44 cm mniejsza, ale plony nasion o 0.61 t·ha^{-1} wyższe od odmian o niezdeterminowanym wzroście. Największą wartość współczynnika zmienności uzyskano dla czasu trwania fazy kwitnienia: 25.9 i 39.3 %, długości łodyg: 24.5 i 21.6 % i plonów nasion: 31.3 i 26.7 % (pierwsza liczba dotyczy odmian tradycyjnych, druga samokończących). Wpływ pogody na kształtowanie długości łodyg oraz zależności pomiędzy długością łodyg a cechami użytkowymi odmian opisano wykorzystując równania regresji pierwszego stopnia. Suma opadów w czerwcu i lipcu oraz w całym okresie wegetacji były dodatnio skorelowane z długością łodyg i ujemnie z plonami nasion, w większym stopniu w grupie odmian tradycyjnych niż samokończących. Przyrost o każde 10 cm długości łodyg roślin odmian o niezdeterminowanym wzroście powodował opóźnienie początku dojrzewania i dojrzałości technicznej o 1 dzień, spadek równomierności dojrzewania o 0.2 stopnia, masy tysiąca nasion o 1.74 g i plonu o 0.135 t·ha^{-1}. Przyrost długości łodyg o każde 10 cm odmian o zdeterminowanym wzroście opóźniał fazę dojrzałości technicznej o 2.5 dnia i zmniejszał równomierność dojrzewania o 0.3 stopnia. Zdeterminowany wzrost wyki siewnej nie wpływał wyraźnie na ograniczenie stopnia wylegania roślin.

KEY WORDS: wyka siewna, odmiany samokończące, długość łodyg, wyleganie

INTRODUCTION

The total farming area put under crops of various vetch species is estimated to be about 1 million ha worldwide, with Turkey, the Russian Federation and Spain having the largest share. In Poland two vetch species have a significant farming value – common vetch (Vicia sativa L. ssp. sativa), and winter vetch (Vicia villosa Roth.), with the cultivation area of approximately 2000 ha [5].

Common vetch is grown mainly for green fodder, but also as a green fertilizer [8]. It can be an important fodder and fertilizer plant in ecological farming [7]. The species has also been found useful in the phytoremedy of soils contaminated by oil [1]. Its seeds, except for some limitations resulting from the presence of antidietary compounds, can be used as fodder [4].

Breeding work oriented at obtaining new cultivars of common vetch has been and still is conducted on a much smaller scale, compared to varieties of species of a high farming value. The significant breakthrough, apart from obtaining cultivars with only trace content of cyanogenic compounds, has come with the varieties of determinate growth, the so-called self-completing ones, developing a top inflorescence that prevents further growth of the stem. From the farming perspective, this is a very important feature, meant to restrict lodging, to make for even maturation, and to curtail the growing period. At present 8 cultivars of common vetch are registered in Poland, of which one, 'Ina', represents a determinate variety [13]. 'Ina' is a cultivar that has high content of cyanogenic compounds, therefore other determinate strains are being tested, of trace content of antidietary compounds.

Length of stem is one of the features significantly modified by environmental and agrotechnical factors [9, 10, 11, 12, 15, 17, 18]. It has been demonstrated that the length of the stem in common vetch indeterminate cultivars is positively related to the number of pods in a plant, to the number of seeds, and as a result, to seed yield from a plant [10]. This feature in an obvious way translates into green matter yields, which in the case of determinate cultivars are about 18 dt·ha^{-1} lower compared to yields obtained from traditional (indeterminate) cultivars [20, 21].

The aim of the present study is to determine the range of relations between weather conditions during the growing period and stem length, and to compare the relation between length of stem and duration of particular developmental phases, lodging, the thousand seed weight and crop yield of determinate and indeterminate cultivars of common vetch.

MATERIALS AND METHODS

The study is based on the results obtained from the registration tests carried out on common vetch cultivars in the years 2001 and 2002 by the Research Centre for Cultivar Testing in six evaluation stations in different parts of Poland. The experiments tested a new determinate strain (SZD), the determinate 'Ina' cultivar, and four

traditional (indeterminate) cultivars -'Jaga', 'Kwarta', 'Fama', 'Niwa'. All the cultivars and the SZD strain are of Polish breed (the Szelejewo Plant Breeding Station).

The years of the experiments widely differed in terms of weather conditions, especially in terms of moisture conditions. In 2001 the total rainfall during the growing period of common vetch was on the average 111.4 mm higher, and mean daily air temperatures 0.8°C lower than in 2002 (Table 1).

The experiments were conducted on brown and pseudopodsolic soils. Soils in Czesławice, Krzyżewo, Pawłowice and Rychliki belong to the best soils in Poland (a wheat complex, good and very good), and in Białogard and Sulejów to the medium soils (a rye complex, very good and good) (Table 2).

The experiments were designed as single-factor ones, in four replications. The area of plots was 14 m^2. Seeding was carried out in the last week of March or in the first week of April. Seed density accepted for calculating seed rate was 200 pieces by 1m^2 . Plants were harvested, depending on location, between 6 and 20 August 2001, and between 30 July and 19 August 2002.

Length of stem was measured from the base of an overground shoot to the top of an inflorescence in the early maturation phase. The measurements were taken on 10 randomly selected plants from each plot. Lodging degree and evenness of maturation were rated according to the 9° scale, where 9° stands for the best, and 1° for the worst. Lodging was evaluated five times during the growing period. As the beginning of blooming stage the moment was accepted when first inflorescence clusters had bloomed on about 10 % of the plants in a plot. The beginning of maturation is when first mature pods occur on about 10 % of plants in a plot, while the phase of technical maturity (corresponding to the condition of being ripe for a single-stage harvest) was the one when pods on the bottom and central nods had been ripe on at least 75 % of the plants.

Coefficients of variability were calculated for duration of developmental phases, stem length, the thousand seed weight, and seed yield. Separately for the groups of indeterminate and determinate cultivars, but irrespectively of the experiment years and soil conditions, regression correlations were sought between precipitation in successive months and total rainfall in the growing period, and length of stem and seed yield, as well as correlations between length of stem and duration of particular developmental phases, evenness of maturation, the thousand seed weight, seed yield, and lodging. In the study only these correlations are presented, where for one or both groups, correlation coefficients were significant at the level of probability of 95 %.

RESULTS

Duration of blooming stage and seed yield were two factors subject to the largest variability in both groups of cultivars; but while blooming stage was more varied in the group of determinate cultivars, seed yield was more varied in the group of traditional cultivars (Table 3). The number of days from the seeding to the beginning of blooming stage, and the number of days from the seeding to technical maturation showed a relatively small variability in both groups of cultivars. A relatively

Table 1 Location of experiments and weather conditions

Name of place /geographic location	Rainfall from seeding to harvest (mm)		Mean daily air temperature from seeding to harvest (°C)	
	2001	2002	2001	2002
Białogard 54°11' N; 15°98' W	325.6	333.5	13.8	15.5
Czesławice 51°30' N; 22°27' W	340.5	215.9	14.7	15.8
Krzyżewo 53°03' N; 22°75' W	327.7	175.2	15.0	15.1
Pawłowice 50°45'N; 18°49' W	413.7	262.0	14.9	15.7
Rychliki 53°98' N; 19°52' W	306.9	156.6	14.6	15.2
Sulejów 51°35' N; 19°88' W	446.1	349.0	15.0	15.5
Mean	360.1	248.7	14.7	15.5

Table 2 Warunki glebowe doświadczeń Soil conditions of experiments

Location	pH_{KCl}	Content of nutrients in soil		
		P	K	Mg
Białogard	6.1/7.0	very high	mean	niska/mean
Czesławice	6.1/6.3	very high	high/mean	mean
Krzyżewo	5.7/6.3	high	mean	mean
Pawłowice	5.7/5.7	very high/mean	mean	mean/low
Rychliki	5.4/6.2	very high	mean/high	mean/low
Sulejów	6.6/5.6	very high/high	high/mean	high/mean

Table 3 Range and coefficients of variability (CV) for duration of developmental phases and selected cropping features of common vetch cultivars

Cechy Traits	Indeterminate cultivars			Determinate cultivars		
	mean	range	CV (%)	mean	range	CV (%)
Number of days from seeding to the beginning of blooming	76	62 - 84	8.0	71	59 - 80	7.3
Number of days from the beginning to the end of blooming	21	8 - 30	25.9	20	9 - 36	39.3
Number of days from seeding to technical maturation	112	101 - 123	5.1	98	81 - 118	11.5
Length of stems (cm)	140.2	72 - 198	24.5	96.1	60 - 143	21.6
Thousand seeds weight (g)	61.6	44.1 – 81.9	15.3	61.5	49.7 – 81.2	14.6
Seed yield ($t \cdot ha^{-1}$)	3.37	1.36 – 5.39	3.13	3.98	1.87 – 5.87	2.67

large variability, more than 20 %, was found for stem length, while the coefficient value was 2.9 % higher for indeterminate cultivars than for determinate ones. The variability coefficient for the thousand seed weight was on the average 15 %, and the difference between the two cultivar groups, although small, indicated that indeterminate cultivars tended to be more varied in this respect. Generally, determinate cultivars were characterized by a larger variability of the duration of developmental phases, while indeterminate ones by a larger variability of cropping features.

A considerable difference appeared between the highest and lowest rainfall sums both during the whole growing period (289.5 mm), and in the last two months of the growing period (184.9 mm). Thanks to such a differentiation in precipitation levels it was possible to demonstrate that stem length, although obviously dependent on the rainfall sum in the whole growing period, was related most strongly to the rainfall sums in June and July (Table 4). At the same time the rainfall negatively affected seed yield of cultivars from both groups. The values of correlation coefficients demonstrate that length of stem and crop yield were more strongly related to rainfall sums in the group of indeterminate cultivars than in the group of determinate ones (Table 5). In addition, determination coefficients indicate that in the group of indeterminate cultivars, 43.8% and 56.7 % of length of stem variance, and 49.1% and 50.6 % of crop yield variance can be accounted for by rainfall sum variance; whereas in the group of determinate cultivars the range was smaller, respectively, 27.9 and 32.2 %, and 34.3 and 48.3 %.

For the group of indeterminate cultivars, a significant correlation was calculated between length of stem on one

Table 4 Relation between rainfall (x) and length of stem (y) of common vetch cultivars

Rainfall (mm)	Group of cultivars	r	Regression equation	D (%)
June and July (98.2 – 283.1)	indeterminate	0.753*	y = 0.509x + 46.581	56.7
	determinate	0.528*	y = 0.215x + 56.896	27.9
Growing period of vetch (156.6 – 446.1)	indeterminate	0.662*	y = 0.261x + 57.637	43.8
	determinate	0.567*	y = 0.135x + 54.083	32.2

*Significant at P<0,05; r- correlation coefficient; D – determination coefficient

Table 5 Relationship between rainfall (x) and yield of seeds of common vetch cultivars

Rainfall (mm)	Group of cultivars	r	Regression equation	D (%)
June and July (98.2 – 283.1)	indeterminate	- 0.701*	y = - 0.1516x + 61.373	49.1
	determinate	- 0.586*	y = - 0.1251x + 62.522	34.3
Growing period of vetch (156.6 – 446.1)	indeterminate	- 0.711*	y = - 0.0899x + 61.737	50.6
	determinate	- 0.695*	y = - 0.0867x + 66.662	48.3

*Significant at P<0,05; r- correlation coefficient; D – determination coefficient

hand, and the number of days from the seeding to the beginning of maturation, the number of days from the seeding to technical maturation, evenness of maturation, the thousand seed weight, and seed yield (Table 6), on the other. For the group of determinate cultivars, a significant correlation was established only between length of stem and date of reaching technical maturation, and between length of stem and evenness of maturation. The highest value of determinate coefficient, accounting for variance relation, was found for length of stem and the date of reaching technical maturation in both cultivar groups, as well as for length of stem and the beginning of maturation, and the thousand seed weight in the group of indeterminate cultivars. All the significant relations are best captured by first-degree regression equations.

In the group of indeterminate cultivars, length of stem was clearly related to the delay in the beginning of maturation. Each 10 cm increase of a length of stem was connected with, on the average, one-day delay in the beginning of maturation. In the group of determinate cultivars, the range of discrepancy in length of stem was smaller (83 cm) than in the group of indeterminate cultivars (126 cm), and the regression was not significant.

For both cultivar groups a significant relation was found between length of stem and the date of reaching technical maturation. At this developmental phase, the coefficients of correlation, determination and regression were higher for the group of determinate cultivars than for the indeterminate group. Each 10 cm increase of a length of stem caused in indeterminate cultivars, on the average, one-day delay in reaching this maturation phase, whereas for determinate cultivars - as much as 2.5-day delay.

In both groups, a negative linear relation was established between length of stem and evenness of maturation. All the coefficients - of correlation, determination and regression – go to prove a stronger relation between these features in determinate cultivars than in indeterminate ones. As the regression equations show, each 10 cm increase of a length of stem led to the decrease of evenness of maturation by 0.2 degree in indeterminate cultivars, whereas in determinate ones – by 0.3 degrees.

A significant negative correlation was found between length of stem and the thousand seed weight, but only in the group of indeterminate cultivars. Plants where length of stem did not exceed 120 cm developed seeds of the thousand seed weight mostly under 70 g. Each 10 cm increase in a length of stem led to the decrease in the thousand seed weight by 1.74 g. In the group of determinate cultivars, plants with the shortest stems (up to 85 cm) formed both the largest seeds (above 75 g) and

Table 6 Relation between length of stem and selected cropping features of common vetch cultivars

Traits	r	Regression equation	D (%)
Indeterminate cultivars			
Beginning of maturation (days)	0.723*	y = 0.1214x + 94.856	52.2
Technical maturation (days)	0.778*	y = 0.1176x + 106.562	60.6
Evenness of maturation (9^o)	- 0.453*	y = -0.0188x + 9.809	20.5
Thousand seeds weight (g)	- 0.617*	y = - 0.1738x + 85.905	38.1
Seed yield ($t \cdot ha^{-1}$)	- 0.420*	y = - 0.1346x + 52.845	17.7
Determinate cultivars			
Beginning of maturation (days)	0.226	regression not significant	5.14
Technical maturation (days)	0.838*	y = 0.2475x + 96.385	70.2
Evenness of maturation (9^o)	- 0.549*	y = -0.0284x + 10.458	30.2
Thousand seeds weight (g)	- 0.381	regression not significant	14.5
Seed yield ($t \cdot ha^{-1}$)	- 0.170	regression not significant	2.89

*Significant at P<0,05; r- correlation coefficient; D – determintation coefficient

the smallest ones (50 - 60 g). The longer the stems, the smaller the difference in seed weight.

In the group of indeterminate cultivars, there occurred a negative relation between length of stem and seed yield, however, the determination coefficient was here relatively low (17.7 %). Each 10 cm increase in a length of stem brought about the decrease in seed yield by 0.135 $t \cdot ha^{-1}$. No relation was established between length of stem increase and seed yield in the determinate cultivars.

Length of stem and degree of lodging were not found to be related. The lodging of plants was in progress from the beginning of blooming to the reaching of maturation, intensifying in the last phase of growing (Fig.1). In the determinate cultivars, lodging took place at the same rate and in a quite similar range as in the indeterminate ones. A certain differentiation became visible only in the blooming phase, when the lodging of the determinate cultivars was graded as 0.25 degree lower than in the indeterminate cultivars.

DISCUSSION

The idea of breeding determinate cultivars of common vetch is to restrict the length of a stem, which should lead to the shortening of the blooming phase, to even maturation, to less lodging, and consequently, to earlier and easier harvesting. So far among crop species of leguminous plants, determinate cultivars of lupin, faba bean, and soya bean have been registered. Unlike common vetch, these are species developing a stiff and straight stem, where the aim of breeding determinate cultivars is to make blooming and maturation regular, and consequently, to shorten the growing season [3, 6, 14, 16].

Length of stem was subject to a large variability, which was due to the different soil and climate conditions; the latter, however, did not neutralize the genetically conditioned differences. Other authors [11, 17] report smaller values capturing the range of variability of this feature, but the investigations were not carried in so varied conditions as own research. Length of stem had a considerable impact on maturation of plants, the thousand seed weight, and seed yield in the indeterminate cultivars, but the impact was significantly weaker in the case of the determinate cultivars, which can be regarded as a success of the breeding work.

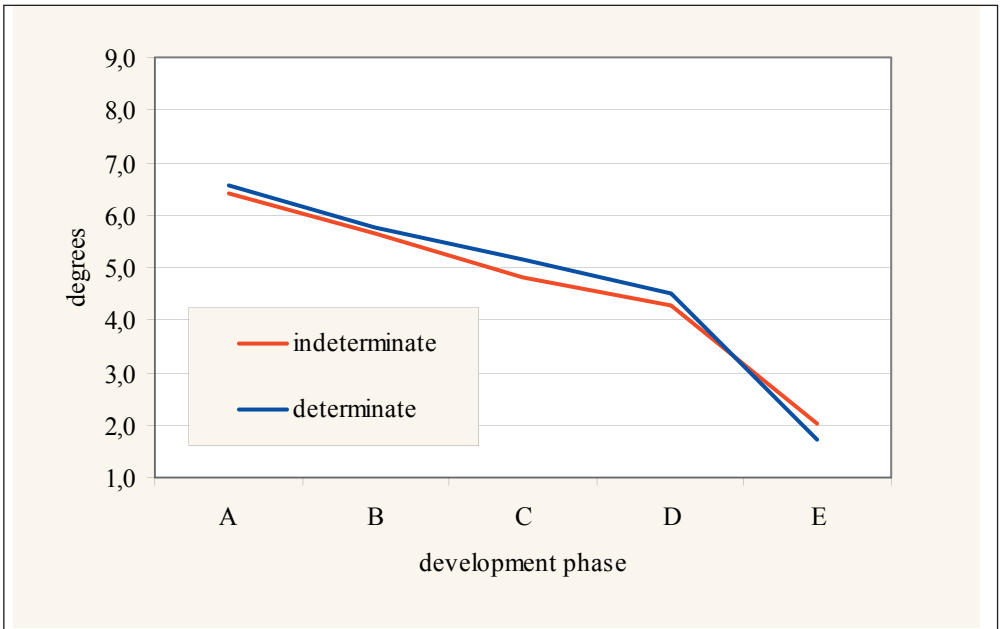
Analysis of relation between length of stem and seed yield is to some extent a simplification. Seed yield is determined by a genotype, and all the consequent elements, above all, the number of pods on a plant, and the number of

seeds from a plant [12, 18]. The longer a stem, the larger, theoretically, number of seeds from a plant should be, but as own research has demonstrated, there is a negative relation between length of stem and seed yield. However, this is true only of traditional, indeterminate cultivars, which can also be counted as a success of the breeding work. The level of crop yield variability, although lower in the determinate group than in the indeterminate group, still remains relatively high.

In most species of crop plants, length of stem is related to the tendency to lodging, however, the relation does not hold for common vetch, just like for the cultivars of Pisum sativum L. [2]. Apart from stem length, other factors that determine the predisposition to lodging are stem thickness and stiffness, and in pea, the type of foliage. Hence growing common vetch in mixed stands remains the only effective way of preventing lodging, also for determinate cultivars. In other experiments that tested the lodging of common vetch, grades were higher than in own research [12]. Grading of lodging is largely subjective, and results of different experiments may be difficult to compare. In this case, it is more legitimate to use the so-called lodging index [19], that is the ratio of conopy height to stem length.

The question that remains to be considered is who could be a target end user of seeding material of determinate cultivars. Green matter yield is determined above all by cutting date, but also by a cultivar type. Green matter yield from determinate cultivars is lower than from indeterminate ones [20, 21]. Because of their shorter stem, these plants should be especially suitable for growing in mixed stands with cereals, as intercrops in stubble fields, where due to a short period of growing they will not reach the blooming phase.

With reference to the aim of the present study, it must be stated that increase in length of stem of plants of indeterminate cultivars leads to the delay in maturation, to less even maturation, and to the decrease in the thousand seed weight and seed yield. Increase in length of stem of plants of determinate cultivars delays reaching the phase of technical maturation and decreases evenness of plant maturation. What counts as a success in the breeding of determinate cultivars, as compared to traditional ones, is the reduction of stem length, and consequently, the relatively small reduction of seed yield variability and its dependence on rainfall during the whole growing period, and especially on rainfall in June and July. However, determinate growth of common vetch does not lead to



A. beginning of blooming of the earliest cultivar,
B. beginning of blooming of the latest cultivar,
C. end of blooming of the earliest cultivar,
D. end of blooming of the latest cultivar,
E. maturity for harvest.

Figure 1. Lodging of plants in the groups of cultivars

the reduction of lodging.

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