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Heterosis effect in synthetic populations of alfalfa (*Medicago media* Pers.)

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SUMMARY – Based on the highest specific combining ability (SCA) of lines in S_5 generation, from nine original synthetic populations of alfalfa, generations Syn-1, Syn-2 and Syn-3 were obtained. Inbred lines were crossed wih *Medicago falcata*, which possessed high fertility genes and genes for few thermal requirements for pod and seed settlement. Synthetic populations were exactly analyzed for seed yield, fresh matter yield and a series of other characters connected with them. Moreover, genotypic response of synthetic populations to soil climatic conditions of Poland was defined. Based on the results obtained from the experiment, three synthetic populations, i.e. no. 4, 5 and 9, with the highest seed and fresh matter yield were selected. In this paper the results related to seed yield and some other characters connected with it are presented.

Key words: Alfalfa, heterosis, fertility, seed, yield.

RESUME – *"L'effet d'hétérosis chez les populations synthétiques de luzerne (*Medicago media *Pers.)". Sur la base de l'aptitude supérieure à la combinaison spécifique des lignées de la génération S_5, à partir de neuf populations originales synthétiques de luzerne on a obtenu les générations Syn-1, Syn-2 et Syn-3. Des lignées parentales consanguines ont été croisées avec* Medicago falcata, *qui possède des gènes de haute fertilité et d'autres gènes de faibles besoins thermaux pour l'établissement de la gousse et de la semence. Les populations synthétiques ont été analysées de façon exacte pour vérifier la production de semence, de matière fraîche et d'autres caractères rattachés. On a défini aussi la réponse génotypique des populations synthétiques aux conditions climatiques du sol en Pologne. En accord avec les résultats obtenus dans cette expérience, on a sélectionné trois populations synthétiques, no. 4, 5 et 9, avec la plus haute production de semence et de matière fraîche. Cette étude présente les résultats relatifs à la production de semence ainsi que d'autres caractères rattachés.*

Mots-clés : *Luzerne, hétérosis, fertilité, semence, production.*

Introduction

Breeding of classic hybrid cultivars of alfalfa is difficult and unprofitable for many reasons. The yield increase of hybrid cultivars (F_1) is not always high enough to make development and maintenance of inbred lines or clones profitable (Busbice, 1986, 1989). Also, the biology of alfalfa flowering, including pollination by insects and often considerable extent of self-pollination, is an obstacle. It prevents making precise crossings between selected genotypes. The increase in green mass and seeds brought about by heterosis in case of alfalfa can be successfully used in breeding synthetic cultivars. They are created as a result of panmictic over-crossing of selected genotypes with proven high combination capacity (Dattée, 1975; Djukic, 1991; Rotili and Zannone, 1991). The aim of this work was the presentation of the heterosis effect in synthetic alfalfa populations Syn-1 and Syn-2 with respect to several chosen traits.

Material and methods

From the developed initial material, 56 inbred lines were selected. They were evaluated in the following generations: S_1, S_2, S_3, S_4 and S_5. Nine synthetic populations were bred from the inbred lines in the S_5 generation with the highest general and specific combination ability (GCA and SCA), expressed by the increase of green mass yield by 20-40% higher if compared to control cultivars, 9 synthetic populations were bred. The inbred lines (S_5) were combined in such a way that in a given synthetic population there were no lines related to each other. An exception were populations No. 5 and 6 made from the related lines in order to determine the influence of affinity on the heterosis effect expressed in the yield of green mass and seeds. Composition of the analysed synthetic populations is given in Table 1. Experiments with

the synthetic populations Syn-1 and Syn-2 were made in a system of completely randomised blocks with four replications. The control cultivars were Radius and Boja. On the 10 m^2 plots, 12 kg seeds/ha were sown in rows 40 cm apart. The synthetic populations were evaluated during three years of full utilisation.

Table 1. Composition of the synthetic populations in the Syn-1 and Syn-2 generations

Synthetic population No.	Inbred lines included in the population	Degree of inbreeding
Syn-1	A3, B10, F1, G1/1	S_5
Syn-2	A3, B10, F1, G1/1	S_5
Syn-3	A3, E1/2, F1, G5/1	S_5
Syn-4	B10, F1, G1/1	S_5
Syn-5	D3, D5, G1/1	S_5
Syn-6	A3, D5, G1/1, G5/1	S_5
Syn-7	D5, E12, G1/1	S_5
Syn-8	D5, E1/2, G5/1	S_5
Syn-9	E1/2, F1, G5/1	S_5

Plants from each synthetic population in the Syn-1 and Syn-2 generations and in the control cultivars Radius and Boja were assessed by observations and measurements of developmental phases and traits related to the yield of green mass and seeds. The hybrid vigour was calculated for 12 traits of 9 synthetic alfalfa populations from the Syn-1 and Syn-2 generations. It was calculated as a value of this trait with respect to its mean value in parent plants. For these traits, the coefficients of repeatability and determination were also calculated. Results are given in Tables.

Results and discusion

The mean yield of green mass for the parental populations was 555.2 dt/ha (Table 2). The hybrid vigour in the populations Syn-1 varied from 20.9 to 136.3%. In the populations of the Syn-2 generation the hybrid vigour fell on average by 15%. An exception was the population No. 5, which in the Syn-2 generation had higher vigour than in Syn-1, i.e. 55.1 and 88.3%, respectively (Table 2). The populations No. 4, 8 and 9 indicated slight fall of the hybrid vigour in the generation Syn-2, whereas the green mass yield for the populations No. 3, 6 and 7 had negative value (Table 2).

The dry mass yield for the parental populations ranged from 112.8 to 180.6 dt/ha (Table 2), while the hybrid vigour in the populations Syn-1 varied from 27.1 to 40.8%. In the Syn-2 populations the hybrid vigour dropped. The value of the fall for different populations varied – from slight for the populations No. 1, 4 and 9 to considerable for the populations No. 3 and 8 (Table 2). An exception was population No. 5 whose dry mass yield in Syn-2 was higher than in Syn-1.

The mean seed yield from 1 ha for the parental populations was 1.45 dt, while the percentage of the hybrid vigour for the yield of seeds from synthetic populations in the generation Syn-1 varied from 133.3 to 461.0% (Table 2) and for the populations No. 2, 4, 5, 8 and 9 was over 250%. In the Syn-2 generation there was a fall in the heterosis effect. An exception was population No. 5 whose percentage of the hybrid vigour in the Syn-2 generation was higher than in Syn-1 by 57.0%, reaching the value of 484.6% (Table 2).

The results of the analysed traits of the synthetic populations in the generations Syn-1 and Syn-2 constituted the basis for calculating repeatability coefficients for the values of these traits in subsequent generation of the population and in subsequent years of the experiment. Calculated repeatability coefficients of some traits are given in Table 3. The highest repeatability was found for the number of shoots (0.837), green mass yield (0.814), dry mass yield (0.834), protein yield (0.825), number of flowers per inflorescence (0.915), number of inflorescences per shoot (0.894), number of pods per fructification (0.856), pod setting (0.924) seed yield (0.837) and number of seeds per pod (0.880). The calculated coefficients of repeatability indicate small changes in the "behaviour" of the population in the Syn-2 generation with respect to the values of the traits obtained in the Syn-1 generation.

Table 2. Characteristics of the heterosis effect in the synthetic populations Syn-1 and Syn-2 of hybrid alfalfa (*Medicago media* Pers.)

Syntheses	Plant height (cm)			Number of shoots (item)			Green mass yield			Dry mass yield			Protein content (%)			Protein yield		
	P†	Syn-1 (%)	Syn-2 (%)	P†	Syn-1 (%)	Syn-2 (%)	P† (dt/ha)	Syn-1 (%)	Syn-2 (%)	P† (dt/ha)	Syn-1 (%)	Syn-2 (%)	P†	Syn-1 (%)	Syn-2 (%)	P† (dt/ha)	Syn-1 (%)	Syn-2 (%)
Syn-1	57.9	44.6	22.8	64.8	10.8	3.4	586.9	136.3	110.2	114.6	40.8	39.2	22.0	4.9	4.0	25.2	14.2	17.4
Syn-2	59.0	12.5	-2.2	65.5	26.0	11.9	526.4	31.1	15.7	119.8	35.4	26.9	21.8	10.0	8.7	26.1	-3.8	-7.0
Syn-3	60.2	4.0	-12.1	63.5	-17.6	-15.9	551.3	-11.1	-20.3	124.3	28.4	7.2	21.6	-0.8	1.9	26.8	-9.0	-5.0
Syn-4	54.4	49.1	43.6	65.2	15.3	4.3	525.4	50.2	48.9	112.8	35.0	33.8	22.1	8.9	7.2	24.9	20.8	23.6
Syn-5	55.4	65.4	55.2	62.0	30.8	31.0	620.4	55.1	88.3	131.8	39.2	47.0	21.9	12.2	15.3	28.9	19.3	24.2
Syn-6	60.0	9.5	-2.2	62.6	-9.3	-10.4	525.6	6.8	-3.3	118.1	-14.6	-20.8	22.1	-15.4	-13.1	26.1	-11.3	-18.8
Syn-7	55.0	9.8	-2.9	64.9	-25.1	-22.7	511.9	-20.9	-26.0	114.3	-27.1	-35.4	22.6	-9.7	-7.1	25.8	-24.3	-14.2
Syn-8	57.5	80.6	78.1	63.4	8.9	5.6	517.9	41.9	37.4	120.6	40.3	18.9	21.8	19.2	10.1	26.3	16.4	16.3
Syn-9	59.4	71.9	69.1	63.5	17.8	22.5	631.2	59.2	53.2	180.6	38.2	37.4	21.5	4.1	3.4	38.9	18.6	10.6
Radius (check)	58.3	46.2††	30.6††	62.8	15.3††	8.6††	580.2	74.6††	59.4††	109.5	28.3††	21.2††	21.4	4.3††	3.1††	25.2	10.2††	8.0††
Boja (check)	57.0	44.2	29.5††	59.2	16.4††	6.2††	574.7	69.3††	51.2 ††	106.6	24.5††	19.4††	22.0	5.8	4.6	26.9	7.3††	5.3††

†Mean value of a trait for parental forms.
††Mean value for synthetic population.

Table 2 (cont). Characteristics of the heterosis effect in the synthetic populations Syn-1 and Syn-2 of hybrid alfalfa (*Medicago media* Pers.)

Syntheses	Number of flowers per inflorescence (item)			Number of inflorescences per shoot (item)			Number of pods per fructification (item)			Pod setting (%)			Seed yield		
	P†	Syn-1 (%)	Syn-2 (%)	P†	Syn-1 (%)	Syn-2 (%)	P†	Syn-1 (%)	Syn-2 (%)	P†	Syn-1 (%)	Syn-2 (%)	P† (dt/ha)	Syn-1 (%)	Syn-2 (%)
Syn-1	17.2	10.6	24.8	35.4	24.3	20.2	6.5	172.3	140.0	33.4	131.7	93.4	1.5	173.3	126.7
Syn-2	16.3	24.3	20.5	26.2	20.5	14.5	6.3	88.9	65.1	34.7	61.4	38.6	1.7	247.1	170.6
Syn-3	16.0	30.2	36.4	27.4	31.4	27.4	6.6	36.4	1.5	32.2	46.9	9.9	1.5	133.3	133.0
Syn-4	18.8	14.1	12.4	39.4	17.2	10.3	5.9	184.7	193.2	33.1	128.4	118.7	1.2	461.0	322.0
Syn-5	17.4	35.4	54.3	36.2	45.2	58.2	6.7	88.1	49.3	40.5	109.2	166.4	1.7	308.6	484.6
Syn-6	15.8	14.3	10.8	28.2	31.4	34.2	6.6	59.1	33.3	21.9	35.7	12.9	1.3	140.0	126.6
Syn-7	17.2	15.0	10.2	20.4	26.2	31.2	6.7	64.2	17.9	32.3	86.9	53.3	1.5	173.3	93.4
Syn-8	15.3	68.5	49.2	32.8	68.4	72.3	6.4	179.7	123.4	31.9	96.2	71.5	1.5	357.5	285.6
Syn-9	18.4	54.3	46.4	40.3	61.4	43.2	6.0	173.3	101.7	41.5	118.4	82.5	1.2	330.9	314.6
Radius (check)	15.4			28.4			9.9			34.5			1.8		
Boja (check)	17.9			31.2			5.4			27.0			1.1		

†Mean value of a trait for parental forms.

Table 3 presents also the coefficients of determination. They define the degree of match between the values of different traits estimated for each population in the Syn-2 and their expected values. The higher the determination coefficient is, the lower the dispersion of the obtained results with respect to the expected ones (Table 3). The determination coefficients were high for plant height (95.8%), green mass yield (91.3%), dry mass yield (89.7%), number of flowers per inflorescence (92.1%), pod setting (95.8%) and number of seeds per pod (93.2%).

Conclusions

(i) Wide range of variability with respect to hybrid vigour observed for green mass yield, dry mass yield, protein yield, number of pods per fructification, pod setting and seed yield can constitute the basis for successful and effective selection of the best synthetic populations.

Table 3. Repeatability coefficients and determination coefficients between the populations of the Syn-1 and Syn-2 generations for selected traits

No.	Trait	Repeatability coefficient	Determination coefficient
1	Number of shoots	0.837**	81.39
2	Plant height	0.791**	95.87
3	Green mass yield	0.814**	91.36
4	Dry mass yield	0.834**	89.78
5	Protein content	0.737**	73.24
6	Protein yield	0.825**	85.34
7	Number of flowers per inflorescence	0.915**	92.10
8	Number of flowers per shoot	0.894**	77.36
9	Number of pods per fructification	0.856**	83.80
10	Pod setting	0.924**	95.89
11	Seed yield	0.837**	76.72
12	Number of seeds per pod	0.880**	93.24

** Significance level $P < 0.01$.

(ii) In the Syn-2 generation, for most populations and analysed traits, a 15% fall in the hybrid vigour was noted. An exception was population No. 5 whose genotype reaction was different. Its hybrid vigour value for most features was higher in the Syn-2 generation than in the Syn-1.

(iii) The highest hybrid vigour value resulting from the heterosis effect was found, for most analysed traits, in the synthetic populations No. 4, 5, 8 and 9. They can be the basis for the next stage of genetic and breeding studies.

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