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Combining Ability of Garden Pea Varieties and Lines through the Vegetation Period Prolongation

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Abstract

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Analysis of combining ability of garden pea (*Pisum sativum* L.) five varieties and one breeding line was made through the vegetation period prolongation and its phenophases. It was establish that non-additive and additive gene effects exerted influence for inheritance of the studied phenophases prolongation and the entire vegetation period. Line 97_3 and Mira variety possessed good general combining ability for breeding of genotype with a long vegetation period. Parent forms Atiroy and Musala were distinguished for low total combining ability, but for high variation of specific combining ability allowing their separated combining to be successfully used for early-maturing breeding.

Key words: Pisum sativum L.,diallel analysis, vegetation period
Abbreviations: CA - Combining Ability, GCA – General Combining Ability; SCA – SpecificCombining Ability, At –Atiroy, Mus – Musala, Vict – Victoria, Mif – Mifelia

Introduction

Right selection of parent forms for crossing takes an important part for the success of the combining breeding. Knowledge for determined property inheritance is a basis for its effective breeding implementation.

Combining ability of the originated forms is used as a criterion for the parent forms selection and as an information source for gene action. The most widespread and tested method for CA estimation is the diallel analysis mostly applied in garden pea breeding (Csizmadia, 1994, Sharma et al., 1999, Srivastava et al., 2000, Bourion et al., 2002).

Genetic control investigations for the vegetation period inheritance and its phenophases were mainly conducted over forage pea in Bulgaria (Naneva, 1981; Popova, 1990).

Purpose of the study is general and specific combining ability investigation over

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garden pea five varieties and one breeding line through the vegetation period prolongation as well as establishment of their importability like donors for breeding of garden pea varieties with different vegetation period prolongation.

Material and Methods

Investigation was carried out at Maritsa Vegetable Crops Research Institute, Plovdiv during the period 2004-2005. Varieties: Mifelia and Victoria (Van Waveren, Germania), Holland variety Atiroy (Royal Sluis RS 2022) and Bulgarian varieties Mira, Musala and 97_3 breeding line were crossed by Griffing diallel scheme (1956) – model 1, model 4. All varieties are wrinkly type, as Atiroy and Musala are early varieties, Mifelia and Victoria – mid-early and Mira and 97_3 breeding line – late.

Comparative trials were set by a block method into four folds upon high smooth bed through scheme 10/20/40/20/10 with 5cm distance in row and 6.4 m^2 plot area. Fifteen hybrid combinations and parent forms were sown every year. The trial was carried out by applicable technology for green pea growing. Phenophases: sowing-emergence, emergence-flowering, flowering -technological maturity and also the vegetation period, recorded /in days/ from emergence to technological maturity.

All indexes concerned a separate plant in the statistical data processing. GCA effects were used for GCA estimation, and SCA effect variations – for SCA (Turbin et al., 1974). Ranging of the means of the parent forms and the hybrid combinations was made by Duncan's Multiple Range test (Duncan, 1955).

Results and Discussion

Data characterizing studied hybrid combinations by their means are shown in Table 1. According to Duncan test made, during three years of study the hybrid combination Atiroy x Musala and Atiroy x Victoria had the shortest vegetation period that authentically distinguished them from the rest crosses. 2005 year was notable for all combinations that were being distributed into six groups with proved differences among individual representatives.

Cross Atiroy x Musala had the shortest phenophase from emergence to flowering during 2004 and 2005. According to that phenophase prolongation the hybrid were distributed into four separate classes: Mira x 97_3 line – the biggest, followed by Mira x Victoria, Mira x Mifelia and 97_3 line x Mifelia, 97_3 line x Victoria and Victoria x Mifelia – the smallest and the rest – into an individual class during 2006.

Phenophasis flowering-technological maturity is with proved high values of hybrid combinations Atiroy x Musala, Musala x Mifelia (2004) and Atiroy x 97_3 (2005) and with the lowest values in the crosses Atiroy x Victoria (2005, 2006) and Atiroy x Mifelia (2006).

Proved differences among the hybrids in the phase sowing-emergence occur only in 2006.

High values for Fisher F criterion were obtained for all periods and years and were significantly exceeded the ultimately meanings showing high reliable differences among the hybrids in respect of the studied property (Table 2). That allowed making of analysis of the parent forms and garden pea line.

Table 1

Means of parents and hybrid combinations by growth phenophasis and vegetation period in days

Phenophases Years	Sowing-emergence			Emergence-flowering			Flowering-technol. maturity			Emergence-technol.maturity		
Parents Crosses	2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006
Atiroy	18.08b	49.03a	26.00b	37.08e	28.98d	37.00c	22.10e	18.03d	18.03d	59.08f	46.95e	55.03d
Musala	17.98b	49.03a	26.00a	37.01e	30.86c	32.13d	25.98b	17.98d	20.01c	63.03e	49.87d	51.95e
Mifelia	18.05b	49.00a	26.03a	49.98c	33.98b	39.05bc	25.05c	20.98c	23.01**a**	75.00c	55.03c	61.98b
Victotia	18.00b	49.03a	26.03a	49.00d	34.10b	42.98a	24.03d	21.25c	15.08f	72.95d	54.98c	58.00c
Mira	18.13b	49.13a	26.03a	56.02**a**	35.00**a**	40.56ab	20.00f	22.98b	21.98b	76.03b	58.03b	64.98**a**
973.00	20.03**a**	49.05a	26.00a	54.08b	34.98**a**	43.05a	27.05**a**	24.98**a**	15.00e	80.95**a**	60.18**a**	58.00c
At x Musala	16.39ab	38.44bcd	17.25e	34.02h	26.12g	39.40e	30.53a	19.48cde	17.27f	64.55g	45.60f	56.67e
At x Mira	15.37ab	38.69abcd	17.81de	48.04abcd	28.03f	41.71c	22.08cdef	21.08bc	20.79c	70.12cd	49.11e	62.50bc
Atiroy x 97_3	15.86abc	38.84abcd	19.13c	47.69bcd	29.43f	40.94cd	20.94ef	24.48a	21.14bc	68.63de	53.91c	62.08cd
At x Vict	16.76a	39.07abc	17.97d	44.69ef	32.78e	41.80c	20.38f	15.38h	15.13g	65.07g	48.16e	56.93e
At x Mifelia	15.20ab	39.05abc	17.62de	45.99de	34.05de	41.10cd	20.74ef	17.37fg	14.75g	66.73f	51.42d	55.85e
Mus x Mira	15.70abc	38.34cd	18.00d	47.24bcd	37.06bc	40.22de	21.46def	17.21fg	19.97cd	68.70de	54.27c	60.19d
Mus x 97_3	14.88a	39.28ab	19.16c	47.01cd	27.76f	40.60cde	23.43bcd	20.47bcd	22.34ab	70.44abc	48.22e	62.94bc
Mus x Vict	15.80abc	39.34a	17.88de	42.99fg	32.74e	41.65cd	24.64b	21.45b	22.59a	67.63ef	54.19c	64.24ab
Mus x Mif	15.55abc	38.33cd	18.31d	42.37g	34.12de	41.32cd	28.67a	20.17bcd	22.19ab	71.04abc	54.28c	63.51abc
Mira x 97_3	15.14ab	38.34cd	17.63de	49.83a	40.83a	47.57a	22.05cdef	18.43ef	17.81ef	71.88ab	59.26b	65.38a
Mira x Vict	15.17ab	38.07d	17.93de	48.72abc	35.72cd	44.54b	22.36cdef	19.36de	17.30f	71.08abc	55.08c	61.84cd
Mira x Mif	14.91a	38.41bcd	17.82de	49.94a	35.44cd	44.35b	20.39f	16.39gh	20.22cd	70.33bc	51.83d	64.57ab
97_3 x Vikt	15.11ab	38.08d	20.50b	48.22abc	38.22b	37.59f	23.71bc	20.45bcd	20.20cd	71.93ab	58.67b	57.79e
97_3 x Mif	15.01a	39.05abc	18.03d	49.18ab	42.15a	44.65b	22.82bcde	19.32de	18.88de	72.00a	61.47a	63.53abc
Vict x Mif	15.12ab	38.71abcd	21.59a	47.15bcd	38.15b	37.36f	23.74bc	20.24bcd	22.90a	70.95abc	58.39b	60.26d

a, b, c,… - Duncan's Multiple Range test ($p \leq 0.01$)

Table 2
Variation analysis of the combining

Variation sources	Variation		
	2004	2005	2006
Sowing-emergence			
Crosses	1.21*	0.71**	5.68***
GCA	0.58	0.15	1.87***
SCA	0.07	0.29	1.14***
Errors	0.15	0.07	0.05
Emergence-flowering			
Crosses	65.82***	92.19***	29.65***
GCA	35.38***	45.00***	8.87***
SCA	4.88***	10.70***	6.46***
Errors	0.43	0.31	0.21
Flowering-technological maturity			
Crosses	34.20***	20.43***	27.62***
GCA	11.66***	3.27***	6.74***
SCA	6.67***	5.77***	5.27***
Errors	0.4	0.25	0.2
Emergence-technological maturity			
Crosses	23.90***	84.26***	38.89***
GCA	13.47***	38.42***	14.29***
SCA	1.50**	10.63***	7.02***
Errors	0.26	0.1	0.42

***$P \leq 0.001$. **$P \leq 0.01$.*$P \leq 0.05$

The results from combining ability dispersion analysis revealed statistical unproved differences for the period sowing-emergence referring to GCA and to SCA in 2004 and 2005 as well as high reliable differences in 2006 (Table 2). The parent forms and the obtained hybrids manifested equally of the means of pheno-phase sowing-emergence by Duncan analysis for the first two years which could explain the obtained results (Table 1). During 2006 the hybrids were grouped into four classes – combination Victoria x Mifelia (21.59 days) had the longest sub period, followed by 97_3line x Victoria, Atiroy x 97_3 and Musala x 97_3 had in a separate group, and all the rest combinations belong to the group with the shortest period.

For the rest sub-periods and generally for the vegetation period a significant variation manifested in regard to GCA and SCA (Table 2). During the three years the mean squares of GCA exceeded the same

Table 3

Estimation of GCA effects, SCA constants, GCA and SCA variations for the period emergence - flowering

Parents	SCA constants					GCA effects	Variations of	
	Musla	Mira	Line 97_3	Victoria	Mifelia		GCA	SCA
2004								
Atiroy	-5.2	1.3	1.41	0.95	1.54	-2.65	6.93	8.18
Musla		2.19	**2.42**	0.94	-0.4	-4.34	**18.75**	**9.63**
Mira			-2.29	-0.86	-0.35	**3.18**	10.02	2.83
Line 97_3				-0.9	-0.65	2.72	7.31	3.26
Victoria					-0.14	0.18	-0.06	0.51
Mifelia						0.9	0.72	0.63
	Standard error - 0.88					0.46		
2005								
Atiroy	0.33	-2.58	-1.51	2.04	1.73	-5.11	**26.08**	3.82
Musla		**4.6**	-5.03	0.14	-0.05	-3.27	10.6	11.41
Mira			**3.22**	-1.69	-3.55	1.55	2.34	**13.16**
Line 97_3				0.48	2.84	1.88	3.47	11.32
Victoria					-0.97	1.69	2.77	1.81
Mifelia						**3.26**	10.56	5.91
	Standard error – 0.68					0.39		
2006								
Atiroy	-0.16	-1.65	-0.65	2.3	0.14	-0.83	0.65	1.96
Musla		-2.69	-0.56	2.59	0.81	-1.27	1.57	3.58
Mira			**2.62**	1.69	0.03	**2.53**	**6.37**	4.87
Line 97_3				-3.5	2.1	0.77	0.55	6.01
Victoria					-3.09	-1.33	1.73	**9.02**
Mifelia						0.13	-0.02	3.5
	Standard error – 0.56					0.32		

ones of SCA (excepting sub-period flowering-technological maturity in 2005) indicating that the control over the analyzed phenophase prolongation inheritance and generally over the vegetation period was executed mainly by additive gene effects. During only 2005 influence for property inheritance had as non-additive so additive gene effects for the phase flowering-technological maturity, and their balance was provoked by environment.

GCA and SCA significant values showed that the parent forms were

Table 4

Estimation of GCA effects, SCA constants, GCA and SCA variations for the period flowering-technological maturity

Parents	SCA constants					GCA effects	Variations of	
	Musla	Mira	Line 97_3	Victoria	Mifelia		GCA	SCA
2004								
Atiroy	4.47	**1.12**	-1.17	-2.2	-2.23	-0.33	0.03	7.79
Musla		-3.02	-2.2	-1.46	**2.19**	**3.19**	**10.08**	**9.99**
Mira			1.51	1.36	-1	-1.91	3.37	3.57
Line 97_3				1.55	0.28	-0.76	0.49	2.45
Victoria					0.73	-0.29	0	2.64
Mifelia						0.09	-0.08	2.54
	Standard error - 0,78					0.45		
2005								
Atiroy	-0.54	**2.64**	*3.38*	-4.16	-1.33	0.17	-0.02	**9.4**
Musla		-1.47	-0.89	1.67	**1.23**	0.42	0.13	1.86
Mira			1.35	1.15	0.97	-1.16	1.29	3.29
Line 97_3				-0.43	-0.71	**1.51**	**2.24**	3.15
Victoria					1.78	-0.05	-0.05	6.16
Mifelia						-0.9	0.76	1.95
	Standard error – 0.61					0.35		
2006								
Atiroy	-1.7	**4.04**	*3.32*	-2.79	-2.86	-2.22	**4.88**	**11.4**
Musla		-0.59	0.71	0.85	**0.75**	**1.6**	2.53	1.11
Mira			-1.6	-2.21	1.01	-0.62	0.35	6.13
Line 97_3				-0.38	-1.41	0.45	0.16	3.9
Victoria					2.53	0.54	0.25	4.82
Mifelia						0.25	0.02	4.39
	Standard error – 0.55					0.32		

distinguished for combining ability which allowed making of individual estimation of each genotype for the sub-periods emergence- flowering, flowering - technological maturity and generally for the vegetation period.

GCA effects for the phase emergence – flowering were high during the three years of trial for Mira variety, followed by 97_3 line and Mifelia variety that possessed High GCA only in 2005 (Table 3). That mean: all crosses including these varieties differ themselves with a long period from emergence to flowering. SCA variations

Table 5

Estimation of GCA effects, SCA constants, GCA and SCA variations for vegetation period – "emergence – technological marurity"

Variety line	SCA constants					GCA effects	Variations of	
	Musala	Mira	Line 97_3	Victoria	Mifelia		GCA	SCA
				2004				
Atiroy	-0.7	**2.43**	0.25	*-1.27*	-0.7	*-2.99*	**8.87**	**1.94**
Musala		-0.8	0.25	-0.53	1.8	*-1.17*	1.32	0.98
Mira			-0.77	0.51	-1.35	1.28	1.58	-0.19
Line 97_3				0.66	-0.38	**1.97**	3.83	-0.19
Victoria					0.65	-0.1	-0.04	-0.19
Mifelia						1.01	0.97	1.33
	Standard error – 0.62					0.36		
				2005				
Atiroy	-0.53	0.21	1.77	*-2.37*	0.94	*-4.9*	**24.01**	2.42
Musala		3.41	-6.33	**2.32**	1.44	*-2.58*	6.62	**14.59**
Mira			2.42	-1.23	-4.81	0.52	0.25	10.48
Line 97_3				0.35	1.8	**2.99**	8.92	13.03
Victoria					0.92	1.62	2.6	3.3
Mifelia						2.35	5.49	7.27
	Standard error – 0.39					0.22		
				2006				
Atiroy	-2.71	2.24	2.26	*0.02*	-2.43	*-3.22*	**9.17**	4.81
Musala		-3.6	0.58	**3.79**	1.32	0.5	0.16	**8.14**
Mira			0.54	-0.08	0.88	**1.98**	3.84	4.44
Line 97_3				-3.7	0.29	1.55	2.3	4.56
Victoria					-0.05	-1.37	1.79	6.7
Mifelia						0.39	0.06	1.81
	Standard error – 0.79					0.46		

of these parent varieties were positive but were varying all along the years. In 2005, the variation was the highest in Mira and exceeded GCA variation compared to the other two years, when GCA variation exceeded that one of SCA. Finally, Mira variety unsustainably inherited the studied property in its progeny.

Atiroy and Musala varieties, having the shortest period from emergence to flowering and reliable differing from the rest parent varieties and lines, showed the negative values of GCA effects during the three trial years (Table 1). SCA variations manifested themselves in a different way – from the highest in 2004 to low (exception of the random derivations variation) in 2006 meaning that individual crosses of these both varieties would be significantly distinguished for the studied phenophase prolongation and combinations with very short and also with very long phenophase emergence-flowering could be expected.

The specific combination Atiroy x Musala (2004) had the highest value for breeding of hybrids with short period from emergence to flowering while the hybrids Musala x 97_3 line (2004), Musala x Mira (2005), Mira x 97_3 line (2005, 2006) were perspective for creation of forms with a longer phase from emergence to flowering.

Data for GCA effects, SCA constants and GCA and SCA variations for the sub-period flowering – technological maturity are presented in Table 4.

Musala variety revealed high GCA in 2004 and 2006, followed by 97_3 line in 2005. Their including in the hybridization in the most cases would lead to higher values of the studied phenophase in the hybrids. The best general combinatory variety reducing strongly the phase prolongation (flowering – technological maturity) with negative values of GCA effects in the three years was Mira variety.

SCA low variations showed that high GCA effects (Musala, 2006) were mainly determined by additive gene effects. The varieties Musala (2004), Atiroy (2005) and 97_3 line (2005) with positive GCA and high SCA variations were very suitable for implementation of crossing with heterosis effect but parent forms with positive GCA and low SCA variations (Musala 2005 and 2006) had bigger influence for the combining breeding.

Combinations Atiroy x Mira, Musala x Mifelia and Atiroy x 97_3 line were the most perspective for breeding forms selection with a longer phenophase flowering - technological maturity according to the SCA constants recorded. Contrary, the crossings Atiroy x Victoria, Atiroy x Mifelia and Musala x Mira which have been stable all the trial period for SCA constant manifestation with negative values could be successfully used for shortening of the studied phase prolongation (Table 4).

It was established that the total prolongation of the vegetation period correlated to the period emergence – flowering (Cumanov et al., 1988). For confirmation: GCA effects behaved equally (table 5). Varieties Atiroy and Musala possessed GCA the lowest effects, and Mira and 97_3 line – the highest ones for the study period.

It can see from the variation analysis of GCA and SCA that GCA variation in Atiroy exceeded that one of SCA for the three trial years, i.e. additive genes affected strongly over the vegetation period inheritance. It was reported for such genetic control by Srivastava et al. (2000).

For the rest parent components (2005, 2006) as well as Mifelia and Victoria in 2004 both gene effects (non-additive and additive) were determining. Similar results in pea were reported by other authors (Sharma et al., 1999).

High GCA for the three trial years was established in 97_3 line and Mira variety for the sub-period emergence – flowering and the entire vegetation period, and in Musala variety – for flowering – technological maturity in 2004 and 2006.

Some parent forms with low negative GCA estimation and high SCA variation could give hybrid combinations exceeding significantly the hybrids which be expected on the basis of the mean value of these lines (Turbin et al., 1974). Such varieties in our trial are Atiroy and Musala.

Conclusions

Differences among the studied parent forms by combining ability for pheno-phasis emergence-flowering, flowering-technological maturity and generally for the vegetation period are proved.

It is confirmed that both non-additive and additive gene effects exert influence for the studied phase's inheritance and the vegetation period.

Line 97_3 has the highest GCA generally for the vegetation period, followed by Mira variety that makes them suitable components for the combining breeding in direction of prolonging of the individual phenophasis and the vegetation period.

The best general combinatory variety reducing strongly the vegetation period prolongation with the negative values for the GCA effects during the three years is Atiroy variety, followed by Musala (2004 and 2005).

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