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COMBINING ABILITY OF SELECTED DESSERT STRAWBERRY CULTIVARS WITH DIFFERENT FRUIT RIPENING PERIODS

Agnieszka Masny[1], Wiesław Mądry[2], Edward Żurawicz[1]
[1]Institute of Horticulture in Skierniewice
[2]Warsaw University of Life Sciences

Abstract. The subjects of the study were the strawberry hybrids of the F_1 generation, derived from the crossing made between eight cultivars: 'Darselect', 'Selvik', 'Elianny', 'Susy', 'Salsa', 'Albion', 'Charlotte' and 'Filon' in an incomplete diallel mating design according to Griffing's method IV. The assessed traits were: fruit ripening time, productivity, fruit size and firmness, as well as soluble solids and ascorbic acid content. Significant differences were found in general combining ability (GCA) and specific combining ability (SCA) effects for most of the traits. The most suitable strawberry for breeding cultivars with fruits for fresh consumption was 'Charlotte', as a donor of high productivity and large fruits. Valuable parental cultivars were also: 'Salsa' – for large fruit rich in soluble solids, 'Darselect' – for high ascorbic acid content, 'Filon' – for large fruit and 'Albion' – for high productivity. Strawberry 'Susy' was the least useful parent for breeding such cultivars. For most families, significantly positive SCA effects were found for the individual traits. Only for 3 families, significantly positive SCA effects were obtained for two or more traits. These are the following families: 'Selvik' × 'Susy', 'Selvik' × 'Salsa' and 'Elianny' × 'Filon'.

Key words: *Fragaria* × *ananassa*, GCA, SCA, breeding value, productivity, fruit quality

INTRODUCTION

One of the objectives of strawberry breeding at the Research Institute of Horticulture in Skierniewice, Poland is to develop new cultivars for fresh market, more valuable than the existing ones. In order to obtain such genotypes, it is necessary to implement breeding programs that take into account the breeding value of parental genotypes determined by their general and specific combining ability for the quantitative traits of interest. General combining ability (GCA) of a parental form for a given trait describes the ability of that parent to pass the trait at some average level to its half-sib progeny [Griffing

Corresponding author: Agnieszka Masny, Fruit Plant Breeding Department, Research Institute of Horticulture, Konstytucji 3 Maja 1/3, 96-100 Skierniewice, Poland, e-mail: agnieszka.masny@inhort.pl

1956a, b, Baker 1978] and is a measure of the additive effect of genes on that trait in the gene pool of the parental forms taking part in the planned mating design [Griffing 1956a, b]. GCA of the parents determines their overall usefulness, with respect to a specific trait, for creating new varieties. The most valuable hybrid progeny in terms of quantitative traits is obtained by crossing parental forms that have favorable GCA effects for these traits [Yashiro et al. 2002, Masny et al. 2008, 2009, Żurawicz et al. 2006].

Specific combining ability (SCA) of a pair of parental forms for a quantitative trait of interest is the genetic interaction of both parents that relates to this trait, expressed in the full-sib progeny. Therefore, the SCA effect is the genetic effect of the interaction of two parents for a given trait, and is the result of the non-additive action of genes (dominance and epistasis) [Griffing 1956a, b, Baker 1978]. In order to determine which genetic effects (additive or non-additive) have a predominant share in the determination (inheritance) of a trait in the progeny, the ratio of mean square for GCA and SCA – $S^2_{GCA} \times (S^2_{SCA})^{-1}$ is analyzed in the analysis of variance according to the fixed model for progeny assessment data obtained in a diallel or factorial mating design [Baker 1978, Hortyński 1987, Żurawicz et al. 1995, López-Sese and Staub 2002]. A high value of this ratio indicates the predominance of additive genetic effects over non-additive effects in the genetic determination of a quantitative trait in the progeny under consideration. This fact signifies a relatively high probability of the trait manifesting itself in the progeny at a level which represents the average of both parents.

The aim of this study was to assess the breeding value of eight dessert strawberry cultivars with different fruit ripening time on the basis of their general and specific combining ability effects for the following traits: fruit ripening time, productivity, fruit size and firmness, and soluble solids (extract) and ascorbic acid (vitamin C) content.

MATERIALS AND METHODS

Plant material and experiment. The study was conducted at the Research Institute of Horticulture in Skierniewice in 2010–2011. It involved seedlings belonging to 18 hybrid families, obtained by crossing eight strawberry cultivars with different fruit ripening time. A description of these cultivars is given by Bosc [2008], Masny and Żurawicz [2009, 2010], Okie [1999, 2002] and Żurawicz and Masny [2010]. The crosses were performed in an open field in the spring of 2008 in an incomplete diallel mating design according to the Griffing's method IV [Griffing 1956b, Dobek et al. 1977, Garretsen and Keuls 1978]. The field experiment with the seedlings was established in the spring of 2009, in the randomized complete block design in 4 replicates, each with 15 plants per plot. All maintenance and protective treatments were carried out in accordance with the recommendations for the commercial plantations.

Traits studied. In 2010–2011, an assessment was made of all the seedlings in the experiment in respect of the following traits: fruit ripening time (expressed as Faedi index, which denotes the number of days from 1 January to harvesting 50% of marketable yield from a plot), marketable yield (g·plot), the number of fruit (per plot), mean fruit weight (g), fruit firmness (N), soluble solids (Brix) and ascorbic acid content in the fruit (mg·100 g of fresh matter). Mean fruit weight was determined as the ratio of marketable yield and the number of marketable fruit per plot. Fruit firmness was measured with an Instron 5542 penetrometer, three times at full ripening, each time on a random sample of 15 fruit from a given plot. Soluble solids content in the fruit was determined using a Rudolph J-157 refractometer on random samples of 15 fruit per plot, selected on three different dates at full ripening, frozen, stored for about 3 months at -20°C, and then homogenized. Ascorbic acid content was determined using an RQ-Easy reflectometer and Merck test strips, on samples prepared in the same way as for the measurement of soluble solids. From the observations of the traits assessed at three different times on each plot average values were calculated, which then served as the experimental data for these traits in the statistical analysis.

Statistical analysis. A two-stage analysis of the data was performed for all the traits studied. Analyses of the data from each year and as two-year averages were performed separately. In the first stage, the SAS MIXED procedure [SAS Institute 2000] was used to perform the analysis of variance of the data from the plots on the basis of a model for a univariate experiment in the randomized complete block design in which it was assumed that the hybrid family was a fixed factor, while the block was a random factor [Möhring and Piepho 2009]. After finding significant variation for the traits among the hybrid families, the second stage of analysis involved performing an analysis of variance of the means for the hybrid families in an incomplete diallel mating design, based on Griffing's fixed model [Griffing 1956b, Garretsen and Keuls 1978, Zhang et al. 2005]. The diallel analysis of variance of the mean-data was performed using the algorithm developed by Garretsen and Keuls [1978]. A detailed analysis of the significance of the GCA and SCA effects was made using a simultaneous test procedure based on the Bonferroni inequality [Garretsen and Keuls 1978].

RESULTS AND DISCUSSION

The diallel analysis of variance of the data from the assessment of the hybrid families showed that in both years of the study both the GCA and SCA effects varied significantly for most of the traits studied (tabs 1, 2). This means that both additive and non-additive genetic effects affect these traits in the progeny. Not significant differences in GCA and SCA effects were obtained only for fruit ripening time (tab. 1) and soluble solids content in 2011 (tab. 2). The highest values of the ratio of mean square for GCA and SCA effects were found for mean fruit weight being around equal to 2 and 3 in the both study years (tab. 1). This means that additive effects predominate in the genetic determination of this trait in strawberry. According to Żurawicz et al. [1995], a large value of the ratio $S^2_{GCA} \times (S^2_{SCA})^{-1}$ for fruit size indicates a relative ease of obtaining large-fruited strawberry varieties. Low ratios of mean square were found for marketable yield (tab. 1). This indicates a high predominance of non-additive (interactive) effects over the additive ones in the genetic determination of this trait. A similar way of fruit yield inheritance was found by Spangelo et al. [1971b] and Gawroński [2011]. For the other traits studied, i.e. fruit ripening time (tab. 1), fruit firmness, and the soluble solids and ascorbic acid content (tab. 2), the ratio of $S^2_{GCA} \times (S^2_{SCA})^{-1}$ ranged from 0.66 to

Table 1. Variance analysis of data on productivity traits, fruit number and weight for progeny families of 8 parental cultivars of strawberry (incomplete diallel mating design, Griffing's method IV; Skierniewice, 2010–2011)

Source of variation	Degrees of freedom	Mean squares								
		fruit ripening time (Faedi index)			marketable yield (kg·plot^{-1})			mean fruit weight (g)		
		2010	2011	2010–2011 average	2010	2011	2010–2011 average	2010	2011	2010–2011 average
GCA	7	1.95**	0.53 ^{ns}	2.05**	2.38**	0.48**	0.59**	3.36**	2.89**	0.52**
CA	10	1.71**	0.68 ^{ns}	1.02**	3.15**	0.83**	0.88**	0.92**	1.55**	0.71**
Random error	51	0.30	0.38	0.30	0.15	0.008	0.04	0.22	0.30	0.12
S^2_g / S^2_s		1.14	0.78	2.00	0.76	0.57	0.67	3.64	1.86	0.73

Explanations: ** – significant differences at α = 0.01 (P < 0.01); * – significant differences at α = 0.05 (P < 0.05); ^{ns} – differences not significant at α = 0.05 (P > 0.05); /^{a} – ratio of mean squares for GCA and SCA

Table 2. Variance analysis of data on fruit quality traits for progeny families of 8 parental cultivars of strawberry (incomplete diallel mating design, Griffing's method IV; Skierniewice, 2010–2011)

Source of variation	Degrees of freedom	Mean squares								
		firmness (N)			soluble solids content (Brix°)			ascorbic acid content (mg·100 ml^{-1})		
		2010	2011	2010–11	2010	2011	2010–11	2010	2011	2010–11
GCA	7	0.25*	0.19**	0.12*	0.99**	0.61 ^{ns}	0.28*	89.39**	88.96*	53.23*
SCA	10	0.14*	0.18**	0.14**	0.93**	0.75 ^{ns}	0.42**	113.20**	37.47^{ns}	42.36*
Random error	51	0.02	0.04	0.04	0.20	0.40	0.12	18.35	31.03	16.87
S^2_g / S^2_s		1.86	1.06	0.85	1.07	0.81	0.66	0.79	2.37	1.25

Explanations: see Table 1

Table 3. GCA effects of 8 strawberry parental cultivars for productivity and fruit weight (incomplete diallel mating design, Griffing's method IV; Skierniewice, 2010–2011)

Parental form	Faedi ripening index			Marketable yield (kg × plot^{-1})			Fruit weight (g)		
	2010	2011	2010–11	2010	2011	2010–11	2010	2011	2010–11
Darselect	-0.47	-0.20	-0.95	-0.72*	-0.29*	-0.51*	-0.39	-0.66	-0.37
Selvik	0.32	0.64	-0.11	1.23*	-0.04	0.57*	0.68*	-1.29*	-0.12
Elianny	0.39	0.14	-0.53	-1.07*	0.66*	-0.23	-1.16*	0.60	-0.30
Susy	0.13	-0.10	0.95	0.04	-0.40*	-0.17	-0.07	-0.50	-0.34
Salsa	0.76*	0.18	0.75	-0.76*	-0.19	-0.46*	2.29*	-0.01	1.05*
Albion	-1.21*	-0.51	-0.20	0.35	0.24*	0.31*	0.05	0.90*	0.34
Charlotte	-0.81*	-0.25	-1.07*	0.31	0.21*	0.27	-1.04*	1.63*	0.17
Filon	0.60	-0.17	1.00*	0.59*	0.08	0.35*	-0.12	1.22*	0.41
SE (g_i)	0.23–0.42	0.26–0.47	0.23–0.42	0.16–0.30	0.04–0.07	0.09–0.16	0.20–0.36	0.24–0.42	0.15–0.26
SE (g_i) × 2.80	0.64–1.178	0.73–1.32	1.00–1.17	0.45–0.84	0.11–0.19	0.25–0.44	0.56–1.01	0.67–1.18	0.42–0.72

Explanation: * – GCA effects significantly different from zero (plus or minus) according to Bonferroni t-test at $\alpha = 0.05$
SE (g_i) – standard error of the estimates of GCA effects

Table 4. GCA effects of 8 strawberry parental cultivars for fruit quality traits (incomplete diallel mating design, Griffing's method 4; Skierniewice, 2010–2011)

Parental form	Firmness (N)			Extract (Brix°)			Vitamin C content (mg·100 ml^{-1})		
	2010	2011	2010–11	2010	2011	2010–11	2010	2011	2010–11
Darselect	0.30	0.01	0.08	0.26	-0.54	-0.14	7.46*	4.17	5.09
Selvik	0.00	0.19	0.12	-0.65*	-0.16	-0.41	-4.96	4.15	-0.18
Elianny	-0.17	0.03	-0.13	0.21	0.03	0.12	2.03	1.43	1.30
Susy	-0.42*	0.29	0.18	0.04	0.65	0.35	1.95	-3.93	-0.26
Salsa	0.02	-0.14	0.09	0.63*	0.12	0.38	-2.47	3.12	0.25
Albion	0.27*	-0.48*	-0.33*	0.26	-0.11	0.07	-0.27	0.25	-0.35
Charlotte	0.18	-0.37	-0.36*	0.52	-0.44	0.04	1.66	-3.83	0.74
Filon	0.02	0.00	0.03	-0.74*	0.29	-0.22	-7.91*	-9.04*	-8.81*
SE (g_i)	0.06–0.11	0.09–0.16	0.09–0.16	0.19–0.35	0.27–0.48	0.15–0.26	1.83–3.29	2.38–3.53	1.75–3.16
SE (g_i) × 2.80	0.17–0.31	0.25–0.45	0.25–0.44	0.53–0.98	0.76–1.34	0.42–0.72	5.12–9.21	6.66–9.88	4.90–8.84

Explanation: see Table 3

Table 5. Estimates of SCA effects of F_1 progeny of strawberry hybrid families for productivity traits, fruit number and weight (incomplete diallel mating design, Griffing's method IV; Skierniewice, 2010–2011)

Cross combination	Faedi ripening index			Marketable yield (kg × $plot^{-1}$)			Fruit weight (g)		
	2010	2011	2010–11	2010	2011	2010–11	2010	2011	2010–11
Darselect × Selvik	-0.28	0.36	0.86	0.94	0.67*	0.83*	0.00	1.78*	1.47*
Darselect × Susy	-1.24	0.48	-0.96	-1.85*	0.15	-0.86*	-0.52	0.09	-0.38
Darselect × Salsa	1.77*	-0.50	0.59	0.49	-0.05	0.21	-1.15	0.56	-0.43
Darselect × Albion	-0.03	-0.41	-0.65	-0.16	-0.39*	-0.28	0.41	0.16	0.20
Darselect × Charlotte	0.25	-0.58	0.61	-0.90	-0.46*	-0.68*	0.75	-1.27	-0.37
Darselect × Filon	-0.46	0.64	-0.45	1.48*	0.08	0.77*	0.51	-1.32	-0.49
Selvik × Elianny	-0.14	0.00	0.92	0.86	0.33*	0.53	-0.04	0.51	0.00
Selvik × Susy	1.26*	-0.36	-0.27	1.00	0.15	0.60*	0.52	-1.51*	-0.69
Selvik × Salsa	-2.51*	0.76	-0.94	-2.93*	0.47*	-1.24*	1.61*	-0.28	0.76
Selvik × Albion	0.56	0.42	0.06	-0.30	-0.90*	-0.59*	-0.79	0.11	-0.46
Selvik × Filon	1.12*	-1.19	-0.62	0.42	-0.72*	-0.13	-1.29*	-0.62	-1.07*
Elianny × Susy	0.41	-0.49	-0.55	-0.96	-1.29*	-1.10*	0.05	-0.87	-0.40
Elianny × Salsa	0.74	-0.26	0.35	2.44*	-0.43*	1.02*	-0.45	-0.29	-0.33
Elianny × Albion	-1.03	-0.48	-1.00	-0.06	0.06	0.02	0.42	-0.79	-0.09
Elianny × Filon	0.03	1.23	0.28	-2.28*	1.33*	-0.46	0.03	1.43*	0.82
Susy × Albion	0.50	0.47	1.59*	0.52	1.23*	0.86*	-0.04	0.52	0.36
Susy × Charlotte	-0.25	0.58	-0.61	0.90	0.46*	0.68*	-0.75	1.27	0.37
Susy × Filon	-0.68	-0.68	0.79	0.38	-0.69*	-0.17	0.75	0.50	0.75
SE (s_{ij})	0.34–0.43	0.39–0.49	0.34–0.43	0.24–0.31	0.05–0.07	0.13–0.17	0.29–0.37	0.34–0.44	0.21–0.27
SE (s_{ij}) × 3.25	1.11–1.40	1.27–1.59	1.10–1.39	0.78–1.01	0.16–0.22	0.42–0.55	0.94–1.20	1.11–1.43	0.68–0.87

Explanation: * – SCA effects significantly different from zero (plus or minus) according to Bonferroni t-test at $\alpha = 0.05$ ($t_{0,05/32\ Ve=93} = 3.25$)
SE (s_{ij}) – standard error of the estimates of SCA effects

Table 6. Estimates of SCA effects of F_1 progeny of strawberry hybrid families for fruit quality traits (incomplete diallel design, Griffing's method IV; Skierniewice, 2010–2011)

Cross combination	Firmness (N)			Extract (Brix°)			Vitamin C content (mg × 100 ml^{-1})		
	2010	2011	2010–11	2010	2011	2010–11	2010	2011	2010–11
Darselect × Selvik	-0.30	-0.18	-0.17	-0.88	0.08	-0.40	-9.21	-0.28	-4.63
Darselect × Susy	-0.15	-0.53	-0.49	1.02	0.10	0.56	5.55	7.30	6.03
Darselect × Salsa	0.58*	0.40	0.27	-0.82	-0.17	-0.49	-8.36	-3.25	-5.39
Darselect × Albion	0.00	0.18	0.39	-0.31	0.19	-0.06	2.66	5.12	4.56
Darselect × Charlotte	0.28	0.27	0.20	1.06	0.85	0.96*	15.17*	-0.13	6.03
Darselect × Filon	-0.42*	-0.14	-0.21	-0.07	-1.06	-0.56	-5.81	-8.75	-6.61
Selvik × Elianny	0.04	-0.18	-0.04	-0.74	0.27	-0.24	-10.33	-0.04	-5.37
Selvik × Susy	0.23	0.74*	0.56*	-0.18	-0.77	-0.47	2.11	-3.52	0.45
Selvik × Salsa	-0.52*	-0.16	-0.06	1.49*	-0.42	0.54	5.06	0.27	2.13
Selvik × Albion	0.21	0.04	-0.10	0.05	0.15	0.10	2.08	-5.03	-1.75
Selvik × Filon	0.35	-0.26	-0.19	0.26	0.70	0.47	10.28	8.60	9.16*
Elianny × Susy	0.19	0.15	0.14	0.78	0.33	0.55	11.87*	-3.46	3.52
Elianny × Salsa	-0.06	-0.24	-0.21	-0.67	0.58	-0.04	3.30	2.99	3.26
Elianny × Albion	-0.16	0.24	0.12	0.22	-0.15	0.04	-5.02	-4.14	-4.20
Elianny × Filon	0.00	0.03	0.00	0.41	-1.03	-0.31	0.18	4.65	2.79
Susy × Albion	-0.05	-0.46	-0.41	0.04	-0.19	-0.08	0.28	4.05	1.38
Susy × Charlotte	-0.28	-0.27	-0.20	-1.06	-0.85	-0.96*	-15.17*	0.13	-6.03
Susy × Filon	0.07	0.37	0.41	-0.59	1.39	0.40	-4.64	-4.49	-5.34
SE (s_{ij})	0.09–0.11	0.13–0.17	0.13–0.16	0.28–0.36	0.39–0.50	0.21–0.27	2.68–3.42	3.49–4.45	2.57–3.28
SE (s_{ij}) × 3.25	0.29–0.36	0.42–0.55	0.42–0.52	0.91–1.17	1.27–1.63	0.68–0.87	8.71–11.12	11.34–14.46	8.35–10.66

Explanation: see Table 5

2.37. This means that both additive and interaction effects are important in the genetic determination of these traits. However, some authors emphasize a predominant share of additive genetic effects over the dominance effects in the inheritance of fruit ripening time [Hortyński 1987], fruit firmness [Shaw et al. 1987, Yashiro et al. 2002] and ascorbic acid content [Lundergan and Moore 1975]. On the other hand, Spangelo et al. [1971a] argue that in the inheritance of fruit firmness and soluble solids content the dominant role is played by non-additive effects, especially the epistatic ones. According to Sherman et al. [1967], many traits in strawberry (e.g. fruit yield, mean fruit weight, or fruit firmness) can be affected by both additive and non-additive effects, but their share in the genetic determination of these traits varies depending on the parents studied.

The estimates of the GCA effects of the parental cultivars for the studied traits are shown in Tables 3 and 4. Low agreement of the GCA effects for ripening time and productivity traits (tab. 3) is clearly apparent in both years of observations. This indicates a significant GCA × Year interaction for these traits. It also creates difficulties in clearly assessing the breeding value of the tested parents on the basis of their GCA effects. By contrast, the GCA effects for fruit quality traits (tab. 4) are more consistent over the years, which manifests a small GCA × Year interaction for these traits.

Similar patterns were also found for the SCA effects. Significantly negative values of GCA effects were found for fruit ripening time in the cultivars 'Albion' and 'Charlotte' (tab. 3). It follows that the progeny of these cultivars were characterized on average by an earlier fruit ripening time, compared with the average time for all the tested families of half-sib progeny of the parents. Among the other parental cultivars, 'Salsa' was characterized by the largest, significantly positive GCA effect for ripening time in the one year. Therefore, this cultivar could be considered a donor of the trait of delayed ripening in the breeding of strawberry cultivars with different ripening periods. Significantly positive values of GCA effects for marketable yield (tab. 3) were found for the cultivars 'Selvik', 'Albion', 'Charlotte' and 'Filon'. These cultivars should therefore be used in the strawberry breeding programs as donors of high productivity. For this trait, however, the cultivars 'Darselect', 'Susy' and 'Salsa' had significantly negative GCA effects, so they are not very useful for strawberry breeding in that direction. From previous studies, it is known that high positive GCA effect showed 'Dukat' [Żurawicz et al. 1995], as well as 'Filon and 'Pandora' [Masny et al. 2008].

Significantly positive GCA effects showed cultivars 'Salsa', 'Charlotte' and 'Filon' for mean fruit weight (tab. 3). Then, these cultivars are useful for breeding large-fruited cultivars. Previous studies have indicated that very useful for breeding large-fruited cultivars are also 'Pegasus', 'Onebor®Marmolada', 'Segal' and 'Camarosa', as well as 'Granda' and 'Darselect' [Masny et al. 2008, Żurawicz et al. 2006]. A confirmation of those studies in practical strawberry breeding is the new Polish cultivar 'Grandarosa', characterized by high productivity and very attractive, large, firm fruit. It is a hybrid of two cultivars 'Granda' and 'Camarosa'. Both of the parental forms are characterized by high breeding value [Żurawicz and Masny 2012]. Significantly negative GCA effects for mean fruit weight showed 'Elianny' and 'Selvik'; their progeny will produce abundant, but also small, fruits. All the statistically significant GCA effects of 'Susy', 'Albion' and 'Charlotte' for fruit firmness were negative (tab. 4). These cultivars are not very useful for breeding dessert cultivars as their progeny will have less firm fruits than the progeny of other parental cultivars. GCA effects for soluble solids content being significantly different from zero were found only in the year 2010 (tab. 4).

These effects were negative for ‘Selvik’ and ‘Filon’, while a significantly positive GCA effect was found for ‘Salsa’, which makes it a donor of high soluble solids, primarily the sugars that largely determine the flavour of the fruit [Deuwer et al. 1967, Shaw et al. 1987]. Only two cultivars had statistically proven GCA effects for ascorbic acid (vitamin C) content (tab. 4). In ‘Filon’, the GCA effect for ascorbic acid content was significantly negative, while in ‘Darselect’ it was significantly positive. Then, ‘Darselect’ will pass relatively high vitamin C content on to its progeny. Fruits with a high ascorbic acid content are highly appreciated by consumers and recommended by nutritionists because of their antioxidant and anticarcinogenic properties [Tulipani et al. 2009]. The obtained results also highlight the difficulty in conducting the breeding of strawberry cultivars, because most traits are inherited independently and it is then almost impossible to obtain hybrids combining several useful traits.

The SCA effects for the traits studied are presented in Tables 5 and 6. For fruit ripening time, significantly positive values of SCA effects were obtained only for the families ‘Darselect’ × ‘Salsa’ and ‘Susy’ × ‘Albion’ (tab. 5). This means that the fruit of the hybrids belonging to these families ripens later than it was indicated by the sum of the GCA effects of both parents. A statistically negative SCA effect for this trait was found in the family ‘Selvik’ × ‘Salsa’. For the progeny from this family, the earlier ripening time, as compared to the sum of the GCA effects of both parents, is a result of the interaction of the genes of both parents, because both parental genotypes belong to a group of late-ripening cultivars [Masny and Żurawicz 2009, Żurawicz and Masny 2010]. Sixteen families of hybrids were shown to have significant SCA effects for marketable yield (tab. 5).

These effects were positive for the families: ‘Darselect’ × ‘Selvik’, ‘Darselect’ × ‘Filon’, ‘Selvik’ × ‘Elianny’, ‘Selvik’ × ‘Susy’, ‘Susy’ × ‘Albion’, and ‘Susy’ × ‘Charlotte’. For the families in which one of the parents is ‘Selvik’, ‘Albion’ or ‘Charlotte’ (with high GCA effects for this trait), interaction with the other parental genotype results in lower yields, which is undesirable. Three hybrid families (‘Darselect’ × ‘Selvik’, ‘Selvik’ × ‘Salsa’ and ‘Elianny’ × ‘Filon’) had significantly positive SCA effects for mean fruit weight, at least in one year of the study (tab. 5), so one should think that the progeny of these families will produce larger fruits as compared to GCA of their parents. Significantly positive SCA effects for fruit firmness were found in ‘Darselect’ × ‘Salsa’ and ‘Selvik’ × ‘Susy’ families (tab. 6). This interaction effect of ‘Selvik’ × ‘Susy’ is favorable for creative breeding, because it allows to obtain progeny that will produce firm fruit despite the fact that the cultivar ‘Susy’ has significantly negative GCA effect for this trait.

Significantly positive SCA effects for soluble solids content were found in ‘Darselect’ × ‘Charlotte’ and ‘Selvik’ × ‘Salsa’ crossings (tab. 6), which means that the fruits of the hybrids within these families will be richer in soluble solids then it could be concluded on the basis of GCA effects of their parents. The high importance of the interaction of both parents in inheritance of this trait was demonstrated by the fact that only one of the above cultivars (‘Salsa’) had positive GCA effect. The significantly positive SCA effects for ascorbic acid content were detected in hybrids derived from the crossings made between ‘Darselect’ × ‘Charlotte’, ‘Elianny’ × ‘Susy’, and ‘Selvik’ × ‘Filon’ (tab. 6).

CONCLUSIONS

1. The strawberry cultivars evaluated in the study vary in their usefulness for creative breeding aimed at improving many important traits.

2. Both additive and non-additive genetic effects play a role in the inheritance of such traits as fruit ripening time, marketable yield, fruit size and quality traits (firmness, soluble solids and ascorbic acid content).

3. Among the assessed parental cultivars, the highest usefulness for breeding dessert strawberry cultivars is shown by ‘Charlotte’. It is a donor of such traits as high productivity and large fruit weight .

4. Valuable parental genotypes for breeding of new strawberry cultivars are also: ‘Salsa’ – donor of genes responsible for large fruit rich in soluble solids, ‘Darselect’ – donor of genes responsible for high ascorbic acid content, ‘Filon’ – donor of the trait of large fruit size, and ‘Albion’ – donor of high productivity.

5. The least useful for the breeding of new dessert strawberry cultivars is ‘Susy’, because of its significantly negative GCA effects for productivity and fruit firmness.

6. In the progeny of three hybrid families, the interaction of genes of both parents contributes to significant improvement two or more important traits. These families are: ‘Selvik’ × ‘Susy’ (high productivity and fruit firmness), ‘Selvik’ × ‘Salsa’ (high yield, large fruit weight, and high soluble solids content), and ‘Elianny’ × ‘Filon’ (high yield and large fruit weight).

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ZDOLNOŚĆ KOMBINACYJNA WYBRANYCH DESEROWYCH ODMIAN TRUSKAWKI O ZRÓŻNICOWANYM OKRESIE DOJRZEWANIA OWOCÓW

Streszczenie. Przedmiotem badań były mieszańce truskawek pokolenia F_1 otrzymane w wyniku skrzyżowania w układzie diallelicznym niekompletnym wg IV metody Griffinga ośmiu odmian: 'Darselect', 'Selvik', 'Elianny', 'Susy', 'Salsa', 'Albion', 'Charlotte' i 'Filon'. Oceniano następujące cechy mieszańców: termin dojrzewania, plenność, wielkość i jędrność owoców, a także zawartość w owocach substancji rozpuszczalnych i kwasu askorbinowego. Stwierdzono istotne zróżnicowanie efektów ogólnej zdolności kombinacyjnej (GCA) i specyficznej zdolności kombinacyjnej (SCA) dla większości badanych cech. Najbardziej przydatna do hodowli odmian deserowych okazała się 'Charlotte', będąca donorem genów warunkujących wysoką plenność i duże owoce. Cenne dla hodowli są również: 'Salsa' – donor cechy dużych i bogatych w substancje rozpuszczalne owoców, 'Darselect' – donor cechy wysokiej zawartości kwasu askorbinowego w owocach, 'Filon' – donor cechy dużych owoców, 'Albion' – donor cechy wysokiej plenności. Najmniej przydatna do hodowli odmian deserowych jest 'Susy'. U większości rodzin stwierdzono istotnie dodatnie efekty SCA dla pojedynczych cech. U trzech rodzin uzyskano istotnie dodatnie efekty SCA dla dwóch lub więcej cech. Są to rodziny otrzymane ze skrzyżowania odmian: 'Selvik' × 'Susy', 'Selvik' × 'Salsa' oraz 'Elianny' × 'Filon'.

Słowa kluczowe: *Fragaria* × *ananassa*, GCA, SCA, wartość hodowlana, plon, jakość owoców

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