INFLUENCE OF SEVERE CONDITIONS ON INHERITANCE OF YIELD AND YIELD COMPONENTS IN JUNE-BEARING STRAWBERRIES AND PROBLEMS OF BREEDING FOR YIELD

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Introduction

The garden strawberry *(Fragaria* x *ananassa* Duch.) has an octoploid status and genomic constitution, originally derived from wild species, which led to wider variability of characters and more chances to select genotypes with desirable trait sets, but their inheritance is quite complex. When combining abilities of parent cultivars are analysed, additive variance is often reported to be prevailing in the inheritance of many characters, including yield [3], however non-additive factor frequently plays a more important role in breeding [4, 9]. Inheritance of yield is complicated by influence of modifying genes on various components affecting it directly or indirectly, which reveal themselves as non-additive effects. Occasions of simple inheritance in the garden strawberry are extremely rare. Genetic control of characters is often impossible to be found out completely, but any finding encourages breeding work. Most breeding programmes in the world are focused on three main goals: high yield, large fruit and high fruit quality [1]. The main objective of the research is to reveal peculiarities of inheritance of yield and chief yield components, directly contributed to it, in rather severe conditions of central Russia [8], and to determine relations between genes affecting yield, having made the findings of use in breeding work.

Objects and methods of investigation

A complete diallel scheme with reciprocal crosses, where ‘Festivalnaya’ (mid-late), ‘Holiday’ (midseason), ‘Rubinovy Kulon’ (early to mid-season) and ‘Troubadour’ (late-season) were tested as parent cultivars (12 crosses in total), was used to study inheritance of yield and four key yield components. The components measured were: branch crown number per plant, inflorescence (truss) number per plant, flower number per truss and average fruit weight (g). Progenies were evaluated in two experiments designed as five randomized blocks n 1997-1998 and 1998-1999 where 40 seedlings represented each cross within each block. The distance between rows was 0,8 m; plants on the rows were spaced 0,35 m apart. Ten plants of each parent cultivar were planted for a comparison. Runner plants were removed. Trusses and flowers were counted in each plant. All marketable fruit (not less than 1,8 mm in the maximum diameter) were counted and weighed to compute average yield per plant and fruit weight.

Progenies, raised from crosses of three cultivars with a clone of *Fragaria virginiana* ssp. *platipetala* Rydb., and those from crosses of six cultivars with a clone of *Fragaria ovalis* Rydb., where the wild species were used as testers, were evaluated in 1998 and 2000, respectively, to learn fruit size inheritance more in detail. ‘Festivalnaya’, ‘Rubinovy Kulon’, ‘Sumas’ etc. and some of their progenies were estimated in 2003 and 2006, after extreme winters, to state their influence on yield. Achene (seed, former pistil) count on a berry and flesh weight per achene were measured in some cultivars/progenies in 2005, using ten typical berries per plot in three successive harvests of mass ripening, to study relations to fruit weight.

Calculation of effects and variances of general (GCA) and specific (SCA) combining abilities to state additive and non-additive components of total genetic variance has been performed using method 3 by Griffing [2]. Standard errors, LSD_{05} and correlations were computed, using Methods of SAS Institute (1989).

Results and discussion

The cultivars, used in the diallel, were different in term of maturing, yield, its dynamics and component characters. Many trusses and high second-year yield distinguished ‘Festivalnaya’ and ‘Troubadour’, while high first-year yield was typical of ‘Rubinovy Kulon’ and ‘Holiday’. ‘Festivalnaya’ and ‘Rubinovy Kulon’ developed large fruit. Plants of ‘Troubadour’ initiated many flowers per truss.

Both GCA and SCA effects played a very important role in yield and yield component inheritance [7]. Branch crown and inflorescence development in ‘Rubinovy Kulon’ in first year, and truss count per plant in ‘Festivalnaya’ and ‘Troubadour’ in second season were inherited by their progenies quantitatively, but ‘Festivalnaya’ passed on its inflorescence type (dichasium) irrespective of cross. Additional examination of progenies from crosses ‘Festivalnaya’ x ‘Honeoye’ (main inflorescence type is umbel) and ‘Festivalnaya’ x ‘Elsanta’ (cyme) in 2003 and 2006, respectively, also proved it. High non-additive effects and variances were found for flower number per truss in ‘Troubadour’ and for fruit size in ‘Rubinovy Kulon’. ‘Festivalnaya’, equally large-fruited, did not pass on the trait. The great role of the non-additive component became especially evident when GCA and SCA variances [7] were compared and given as GCA-to-SCA ratios (Tabl. 1).

The progenies of several cultivars from crosses with the two octoploid testers gave additional information. The clone of *F. ovalis* was early ripening and very small-fruited (0,5 g). *F. virginiana* produced larger fruit (1,3 g) of mid-late term of maturing. However progenies from crosses with *F. ovalis* had bigger amounts of large-fruited seedlings (Tabl. 2), particularly the combination ‘Rubinovy Kulon’ x *F. ovalis,* while all the progenies of *F. virginiana* developed fruit of comparable sizes, however produced more trusses. Therefore, some genes/alleles, responsible for truss initiation, could suppress genes controlling fruit size character. Gene(s) driving fruit size character in ‘Rubinovy Kulon’ behave as dominant (or epistatic), but the dominance can be suppressed. Conversely, fruit size in ‘Festivalnaya’ is under control of additive alleles/genes, but it possesses more genes contributing to the trait. Genes/alleles, conferring plant branching and the inflorescence type, named ‘dichasium’, appear to be dominant. In their turn, dormancy of axillary buds and plant branching are dependent on weather conditions [6].

Table 1

GCA-to-SCA ratios for yield component characters, calculated for four parent cultivars in the diallel scheme (1997-1999)

Yield component	Festivalnaya	Holiday	Rubinovy Kulon	Troubadour
Branch crown number per plant in 1st cropping year	4.8	1.2	2.9	8.7
Branch crown number per plant in 2nd cropping year	6.3	1.9	3.7	17.0
Inflorescence number per plant in 1st cropping year	3.8	1.7	15.8	1.8
Inflorescence number per plant in 2nd cropping year	4.5	2.0	4.3	2.9
Flower number per inflorescence in 1st year	2.0	2.0	4.3	3.0
Average fruit weight in 1st cropping year	0.4	0.4	0.4	0.5
Average fruit weight in 2nd cropping year	0.7	0.1	0.1	0.6

A later start of flower initiation because of late fruit maturing and a longer period of time, needed to build up a dichasium compared with a cyme [5], result in incompleteness of some trusses. New inflorescences, initiated in spring, are added to them. Many cultivars in second cropping year have comparable flower counts per truss for the same reason.

Table 2

Average fruit weight of cultivars and their progenies (g), raised from crosses with clones of *F. virginiana* ssp. *platypetala* (1997) and *F. ovalis* (2000)

Cross	Fruit weight of cultivar	Amount of seedlings, fruit weight of which exceeded 4 g, %	Fruit weight of progeny
Feierverk x *F. virginiana*	11.5	2.1	3.25±0.11
Konservnaya Plotnaya x *F. virginiana*	10.3	2.0	3.24±0.13
Rubinovy Kulon x *F. virginiana*	11.1	1.9	3.47±0.13
Feierverk x *F. ovalis*	11.5	22.8	3.88±0.13
Festivalnaya x *F. ovalis*	10.5	5.8	2.81±0.14
Holiday x *F. ovalis*	9.7	4.9	2.25±0.13
Redgauntlet x *F. ovalis*	10.7	17.6	3.72±0.16
Rubinovy Kulon x *F. ovalis*	11.1	58.1	4.22±0.10
Senga Sengana x *F. ovalis*	9.9	14.7	2.76±0.15

• Standard error is given at P = 0.05.

Ogoltsova and Bayanova [4] supposed that winter hardiness of cultivars, participated in crosses, might be a reason of high values of SCA effects and variances. Severe frosts with poor snow cover in both late autumn [8] and early spring are typical, while winter months are rich in deep thaws and temperature fallings following them. Plants of ‘Festivalnaya’, having deep dormancy of flower buds and tolerance to freezing, preserve most initiated inflorescences. Late-season ‘Troubadour’ is vulnerable to freezing in the late fall, while ‘Rubinovy Kulon’ has shallow dormancy in late winter, which resulted in inflorescence loss. It is compensated with an increment in fruit weight [6]. ‘Rannyaya Plotnaya’, examined in 2003, as well as ‘Rubinovy Kulon’, ‘Senga Sengana’ and their progenies from crosses with ‘Alpha’, evaluated in 2006, after extreme winters, developed larger fruit, while ‘Sumas’ and its seedlings, most winter hardy, produced fruit of about the same size as usual (data not presented).

Genes, responsible for fruit shape, achene number, flesh weight per achene etc., play a certain role. Extensive variability of fruit shape indicates it as influenced by many genes/alleles. Achenes on a berry surface of ‘Rubinovy Kulon’ are spaced distantly from each other, whereas numerous achenes of ‘Feierverk’ are arranged closely (Tabl. 3).

Table 3

Average fruit weight, achene number per berry and 1 cm^2, and flesh weight per achene in some cultivars and progenies (2005, second cropping year)

Cultivar/Family	Average fruit weight, g	Achene number per berry	Achene number per 1 cm^2	Flesh weight per achene, mg
Alpha	11.6	519.2	22.9	22.3
Feierverk	11.7	718.6	27.0	16.3
Festivalnaya	11.2	574.3	24.1	19.5
Rubinovy Kulon	11.8	389.2	17.6	30.3
Rusitch	12.0	491.0	19.5	24.4
Senga Sengana	10.7	479.5	23.3	22.3
Alpha x Rubinovy Kulon	11.1	441.6	20.3	25.1
Alpha x Rusitch	11.3	505.7	20.9	22.3
Feierverk x Rubinovy Kulon	11.1	622.8	24.3	17.8
Festivalnaya x Feierverk	10.6	612.6	25.9	17.3
Festivalnaya x Rubinovy Kulon	10.5	435.8	20.8	24.1
Festivalnaya x Senga Sengana	9.8	481.7	23.2	20.3
Senga Sengana x Feierverk	9.6	598.6	26.8	16.0
Senga Sengana x Rubinovy Kulon	10.8	421.1	20.1	25.6
LSD_{05}	1.4	56.8	2.3	4.8

Fruit weight was correlated neither with achene number per berry nor with flesh mass per achene, but was correlated with the combination of these traits (R = 0.92), inherited independently. 'Feierverk' passes on high achene numbers, but its progenies still have intermediate quantities, while low flesh weight per achene was strictly inherited, which resulted in smaller fruit. The other cultivars did not pass on the trait as steadily. Plants of 'Feierverk' produce oblong flattened berries with many achenes and low flesh mass per achene. The genes are likely to be linked to genes driving fruit shape, seed mass etc.; yet such links may be broken. Some seedlings from crosses between 'Rubinovy Kulon' and 'Festivalnaya' formed very large fruit, combining numerous achenes with high flesh weight per achene.

Conclusions

Genes through processes running in plants drive habits and peculiarities of plant development, which directly or indirectly influence on yield component values. The chief habits and traits affecting yield components are following: 1) dormancy of axillary buds; 2) type of plant branching and development; 3) conditions to begin initiation of inflorescences and its further control; 4) specific inflorescence number per branch crown; 5) inflorescence type; 6) fruit shape; 7) amount of pistils (subsequent achenes) per flower; 8) specific flesh weight per achene.

Modifying effects should be expected from genes driving various physiological processes, connected with: 1) duration and depth of winter dormancy; 2) tolerance to freezing in different terms during overwintering; 3) time of flowering and maturing; 4) tolerance to late spring frosts; 5) reaction to environmental conditions.

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