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Heterosis effect of some onion (Allium cepa L.) characteristics

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Abstract

The object of the studies in 1977 was a population of 15 F_1 hybrids, 11 F_2 progenies, 16 parental forms (8 malesterile A lines and 3 inbred C lines). Heterosis of onion bulb weight, height, diameter was high. The heterosis of bulb firmness, skin adherence and sugar content was not high. The heterosis of other characteristics was rather low.

INTRODUCTION

Development of F_1 hybrids with bulbs possessing desirable utilitarian traits is possible due to studies on the crossing ability of maternal, that is, male-sterile, lines and inbred paternal lines, C, having fertile pollen (Jones and Clarke, 1943-1947; Jones and Davis, 1944; Erickson and Gabelman, 1954; Kobabe, 1958; Doruchowski, 1968, 1969, 1971, 1978; Brezhniev, 1971; Dowker and Fennell, 1974; Feltz, 1975; Arunachalm, 1977).

Parental lines are usually developed from varieties having the most desirable traits. The crossing ability of a certain number of hybrids and their production value, mainly in respect to yield and uniformity of bulb characteristics, were studied in 1966-1967 (Doruchowski, 1968). In this study, the results are presented on the heterosis of the following traits: bulb weight, height, diameter, collar thickness, dry skin thickness, bulb firmness, root disc diameter and dry matter and sugar contents.

MATERIALS AND METHODS

The studies were done at the Research Institute of Vegetable Crops in 1977-1978. The materials used in this study are described in the first part of this series of papers (Doruchowski, 1986).

Bulb weight is expressed in dag, bulb height, diameter, collar thickness and root disc diameter in cm, dry skin thickness in μ, and bulb firmness in readings from 1-100 of a Type No. 2 durometer from the Shore Instrument and MFG Co., Inc. 90-35 Van Wyck Expressway, Jamaica, N.Y. 11435 U.S.A. Samples numbering from 19-100 bulbs were picked randomly from three replications.

The chemical composition of the onions was determined in cooperation with the Departmen of Food Processing and Freezing of the Research Institute of Vegetable Crops in Skierniewice. The dry matter content in percent of fresh weight was determined by initial drying at a temperature of 60-70°C, next at 105°C until a constant weight was attained. Additionally, dry matter was determined refractometrically.

The simple and total sugar contents were determined by the Loof--Schoorl method in percentage of fresh weight. The differences between the mean values for the parental forms and their F_1 and F_2 hybrids were evaluated using Student's t test at a significance level of $\alpha=0.05$.

The heterosis effect (Tables 1-8) was expressed as the percentage ratio of the average values for F_1 hybrids to the mean for the parental line with the higher trait value:

$$H = \overline{X}_{F_1} : \overline{X}p_{max} \cdot 100\%$$

RESULTS

The average onion bulb weight in most of the maternal components, that is, male-sterile A lines, was higher than in the paternal, inbred C lines, with the exception of A-63, A-16, C-177b, C-181 and C-16 (Table 1). The bulb weight of 8 F_1 hybrids among the 15 in 1977, and 4 F_1 hybrids among 12 in 1978, was significantly higher than that of both parental components. The best in this respect were, in 1977 — F_1 hybrids: A-16×C-16 and A-19×C-19, which exhibited the highest heterosis effect. The weight of 3 F_1 hybrids was on the same level as that of line A, of 3 others, below it. Only F_2 hybrid A-16×C-141 had an average weight somewhat smaller than F_1. The remaining hybrids had weights significantly smaller than the weight of F_1 hybrid bulbs and similar to that of one of the parents, due to segregation of traits.

The very unfavorable atmospheric conditions for onion growth which occurred in 1978, negatively influenced heterosis, which was slightly noticeable in the weight of F_1 hybrid bulbs. In connection with this, the mean bulb weight for both parental and F_1 hybrid forms was very differentiated and, in most cases, low.

Table 1

Mean values ($\bar{x}$) and heterosis effect of onion bulb weight (dag)

No.	Hybrid formula	1977					1978			
		$\bar{x}$				heterosis efect	$\bar{x}$			heterosis effect
		line A	line C	F_1	F_2	H according to P_{max}	line A	line C	F_1	H according to P_{max}
1.	A-6 × C-177a	11.9c	9.4b	11.6c	7.6a	97.5	—	—	—	—
2.	A-16 × C-177a	11.0c	9.4b	15.7d	8.5a	142.7	13.0b	6.6a	12.0b	92.3
3.	A-54 × C-177a	16.7d	9.4b	14.1c	6.0a	84,4	9.5b	6.6a	11.8c	124.2
4.	A-58 × C-177a	13.4b	9.4a	10.3a	—	76.9	—	—	—	—
5.	A-125 × C-177a	12.1b	9.4a	14.4c	8.6a	119.0	7.5a	6.6a	7.8a	104.0
6.	A-19 × C-177a	11.9c	9.4a	13.8c	—	116.0	—	—	—	—
7.	A-181 × C-177a	18.1c	9.4a	14.0b	—	77.3	11.1c	6.6a	8.7b	78.4
8.	A-63 × C-177b	9.2a	11.3b	13.1c	10.6b	115.9	—	—	—	—
9.	A-16 × C-141	11.0b	9.4a	13.7c	12.5c	124.5	—	—	—	—
10.	A-58 × C-141	13.4b	9.4a	13.3b	—	99.2	10.4c	5.8a	8.0b	76.9
11.	A-12 × C-141	—	—	—	—	—	9.4b	5.8a	12.8c	136.2
12.	A-125 × C-181	12.1b	15.0c	16.9d	8.1a	112.7	7.5a	9.1b	14.2c	156.0
13.	A-181 × C-181	—	—	—	—	—	11.1b	9.1a	13.0c	117.1
14.	A-16 × C-16	11.0a	15.5c	15.7c	13.7b	101.3	13.0b	11.4b	9.5a	73.1
15.	A-6 × C-6	11.9bc	7.5a	12.8c	11.2b	107.6	—	—	—	—
16.	A-125 × C-199	12.1b	10.2a	14.2c	11.1ab	117.3	—	—	—	—
17.	A-19 × C-19	11.9a	11.0a	17.3c	13.8b	145.4	—	—	—	—
18.	A-16 × C-9	—	—	—	—	—	13.0b	6.4a	11.9b	91.5
19.	A-101 × C-9	—	—	—	—	—	11.2b	6.4a	10.6b	94.6
20.	A-181 × C-9	—	—	—	—	—	11.1b	6.4a	15.5c	139.6

Mean values denoted by the same letter do not differ significantly ($a = 0.05$) by Student's. t — test. Evaluation of differences was done within the hybrid formula.

The mean bulb height was, in most of the paternal components, significantly higher than in the maternal ones, and also in some cases, greater than in F_1 and F_2 hybrids (Table 2). The onion bulbs in the paternal lines C had a more or less elongated shape and so their height was greater than their diameter. The height of F_1 hybrid bulbs was intermediate in comparison with parental forms, or significantly higher in F_1 hybrids (A-16×C-177a), (A-19×C-177a), (A-6×C-6) and (A-125×C-199) than in the higher of the parents, exhibiting evident heterosis. In F_2, this trait was close to parental from values because of trait segregation.

The bulb diameter in most A lines was significantly greater than in C lines and in some of the F_1 hybrids (Table 3). However, the average diameter of bulbs from C lines was significantly smaller than in F_1 hybrids. The F_1 hybrids which had a large mean bulb diameter also had a large mean weight and exhibited the highest heterosis of both diameter and weight: F_1 (A-16×C-177a), (A-16×C-141), (A-6×C-6) and (A-19×C-19). Due to this, there is a realistic possibility of increasing the yield by introducing these F_1 hybrids into production.

The mean bulb diameter of F_2 hybrids was similar to that in lines A and C because of segregation of these traits and parental characteristics thereby becoming evident.

The mean collar thickness was only sligthly higher (5%) in 3 F_1 hybrids (A-63×C-177b), (A-6×C-6) and (A-125×C-199) showing heterosis (Table 4). As results from this, most of the hybrids did not have thick collars, which is a very desirable trait from the standpoint of production.

All of the C lines, with the exception of C-19, had a mean dry skin thickness which was larger than that of A lines (Table 5), Heterosis of dry skin thickness was not found in the majority of F_1 hybrids, with the exception of (A-125×C-181). The results suggest that in order to improve the quality of the dry skin in F_1 hybrids, the parental components should be chosen so that they both have thick, strong and well adhering dry skin. Individuals of better quality than that of A line can be selected from F_2 hybrids.

The mean bulb firmness in 1977 in 2 F_1 hybrids was significantly greater than in line C in comparison with bulb firmness in line A and the remaining F_1 and F_2 hybrids, with the exception of line A-63 (Table 6). Evident heterosis was found only in F_1 (A-19×C-19). The bulb firmness in F_2 hybrids was significantly lower than in F_1 hybrids. The F_2 generation (A-16×C-141) was an exception, having a higher value. The differences were significant at the $\alpha = 0.05$ level.

In order to improve bulb firmness in F_1 hybrids, a large number of various parental forms or lines with firm bulbs are necessary. These

Table 2

Mean values ($\bar{x}$) and heterosis effect of onion bulb height (cm)

No.	Hybrid formula	1977 $\bar{x}$ line A	1977 $\bar{x}$ line C	1977 $\bar{x}$ F_1	1977 $\bar{x}$ F_2	1977 heterosis effect H according to P_{max}	1978 $\bar{x}$ line A	1978 $\bar{x}$ line C	1978 $\bar{x}$ F_1	1978 heterosis effect H according to P_{max}
1.	A-6 × C-177a	6.6a	7.1c	6.7ab	6.8b	94.4	—	—	—	—
2.	A-16 × C-177a	6.9b	7.1c	7.3d	6.4a	102.8	6.8b	6.5a	6.7ab	98.5
3.	A-54 × C-177a	7.0b	7.1bc	7.2c	6.7a	101.4	5.8a	6.5b	6.4b	98.5
4.	A-58 × C-177a	7.5c	7.1b	6.5a	—	86.7	—	—	—	—
5.	A-125 × C-177a	7.1b	7.1b	7.3c	6.8a	102.8	5.4a	6.5b	5.5a	84.6
6.	A-19 × C-177a	6.0a	7.1b	7.1b	—	100.0	—	—	—	—
7.	A-181 × C-177a	6.4a	7.1c	6.7b	—	94.4	5.9b	6.5c	5.7a	87.7
8.	A-63 × C-177b	5.9a	7.4c	6.9b	7.3c	93.2	—	—	—	—
9.	A-16 × C-141	6.9a	9.3c	7.6b	7.9b	81.7	—	—	—	—
10.	A-58 × C-141	7.5b	9.3c	6.7b	—	72.0	6.7a	7.1b	6.6a	92.9
11.	A-12 × C-141	—	—	—	—	—	6.6a	7.1b	6.7a	94.4
12.	A-125 × C-181	7.1b	8.0d	7.6b	6.5a	95.0	5.4a	5.4a	7.4b	137.0
13.	A-181 × C-181	—	—	—	—	—	5.9b	5.4a	6.5c	110.2
14.	A-16 × C-16	6.9b	7.7c	6.8b	6.2a	88.3	6.8b	6.6b	5.8a	85.3
15.	A-6 × C-6	6.6b	6.2a	6.8b	6.6b	103.0	—	—	—	—
16.	A-125 × C-199	7.1a	7.0a	7.4b	7.2ab	104.2	—	—	—	—
17.	A-19 × C-19	6.0a	9.0d	6.9b	7.3c	76.7	—	—	—	—
18.	A-16 × C-9	—	—	—	—	—	6.8b	6.5a	6.5a	95.6
19.	A-101 × C-9	—	—	—	—	—	5.9a	6.5b	6.5b	100.0
20.	A-181 × C-9	—	—	—	—	—	5.9a	6.5b	6.5b	100.0

Explanations as in Table 1.

Table 3

Mean values ($\bar{x}$) and heterosis effect of onion bulb diameter (cm)

No.	Hybrid formula	1977					1978			
		$\bar{x}$				heterosis effect	$\bar{x}$			heterosis effect
		line A	line C	F_1	F_2	H according to P_{max}	line A	line C	F_1	H according to P_{max}
1.	A-6 × C-177a	6.4c	5.5b	6.3c	5.1a	98.4	—	—	—	—
2.	A-16 × C-177a	6.2b	5.5a	7.0c	5.5a	112.9	6.6c	4.7a	6.4b	97.0
3.	A-54 × C-177a	7.4d	5.5b	6.7c	4.7a	90.5	6.0b	4.7a	6.4c	106.7
4.	A-58 × C-177a	6.7c	5.5a	6.1b	—	91.0	—	—	—	—
5.	A-125 × C-177a	6.4b	5.5a	6.7c	5.3a	104.7	5.3b	4.7a	5.0ab	94.3
6.	A-19 × C-177a	6.8b	5.5a	6.6b	—	97.1	—	—	—	—
7.	A-181 × C-177a	7.8c	5.5a	6.9b	—	88.5	6.3c	4.7a	5.8b	92.1
8.	A-63 × C-177b	5.8a	5.9a	6.6b	5.8a	111.9	—	—	—	—
9.	A-16 × C-141	6.2b	4.7a	6.5c	6.1b	104.8	—	—	—	—
10.	A-58 × C-141	6.7b	4.7a	6.5b	—	97.0	6.1c	4.2a	5.3b	86.9
11.	A-12 × C-141	—	—	—	—	—	5.5b	4.2a	6.5c	118.2
12.	A-125 × C-181	6.4b	6.5b	6.9c	5.3a	106.1	5.3a	5.7b	6.4c	112.3
13.	A-181 × C-181	—	—	—	—	—	6.3b	5.7b	6.5b	103.2
14.	A-16 × C-16	6.2a	6.8b	7.1c	7.0bc	104.4	6.6b	6.1a	5.9a	89.4
15.	A-6 × C-6	6.4bc	5.5a	6.5c	6.2b	101.6	—	—	—	—
16.	A-125 × C-199	6.4b	5.7a	6.6b	5.8a	103.1	—	—	—	—
17.	A-19 × C-19	6.8b	5.5a	7.3c	6.7b	107.3	—	—	—	—
18.	A-16 × C-9	—	—	—	—	—	6.6b	4.6a	6.4b	97.0
19.	A-101 × C-9	—	—	—	—	—	6.3b	4.6a	6.0b	95.2
20.	A-181 × C-9	—	—	—	—	—	6.3b	4.6a	7.1c	112.7

Explanations as in Table 1.

Table 4

Mean values ($\bar{x}$) and heterosis effect of collar thickness (cm)

No.	Hybrid formula	1977 $\bar{x}$ line A	1977 $\bar{x}$ line C	1977 $\bar{x}$ F_1	1977 $\bar{x}$ F_2	1977 heterosis effect H according to P_{max}	1978 $\bar{x}$ line A	1978 $\bar{x}$ line C	1978 $\bar{x}$ F_1	1978 heterosis effect H according to P_{max}
1.	A-6 × C-177a	1.8c	1.8c	1.7b	1.2a	94.4	—	—	—	—
2.	A-16 × C-177a	1.7b	1.8c	1.8c	1.3a	100.0	1.5a	1.5a	1.5a	100.0
3.	A-54 × C-177a	1.9c	1.8b	1.9c	1.1a	100.0	1.4a	1.5b	1.4a	93.3
4.	A-58 × C-177a	1.8b	1.8b	1.6a	—	88.9	—	—	—	—
5.	A-125 × C-177a	1.8b	1.8b	2.0c	1.3a	111.1	1.2a	1.5b	1.3ab	86.7
6.	A-19 × C-177a	1.4a	1.8b	1.8b	—	100.0	—	—	—	—
7.	A-181 × C-177a	1.6a	1.8c	1.7b	—	94.4	1.5b	1.5b	1.4a	93.3
8.	A-63 × C-177b	1.9b	1.9b	2.0c	1.5a	105.3	—	—	—	—
9.	A-16 × C-141	1.7b	1.8c	1.8c	1.4a	100.0	—	—	—	—
10.	A-58 × C-141	1.8b	1.8b	1.5a	—	83.3	1.5c	1.2a	1.3b	86.7
11.	A-12 × C-141	—	—	—	—	—	1.5b	1.2a	1.5b	100.0
12.	A-125 × C-181	1.8c	1.9c	1.4b	1.2a	73.7	1.2a	1.3b	1.5c	115.4
13.	A-181 × C-181	—	—	—	—	—	1.5b	1.3a	1.5b	100.0
14.	A-16 × C-16	1.7c	1.8d	1.6b	1.2a	88.9	1.5b	1.6b	1.3a	81.2
15.	A-6 × C-6	1.8c	1.6b	1.9d	1.4a	105.5	—	—	—	—
16.	A-125 × C-199	1.8b	1.8b	1.9c	1.4a	105.5	—	—	—	—
17.	A-19 × C-19	1.4a	1.9d	1.8c	1.5b	94.7	—	—	—	—
18.	A-16 × C-9	—	—	—	—	—	1.5b	1.3a	1.5b	100.0
19.	A-101 × C-9	—	—	—	—	—	1.4b	1.3a	1.5b	107.1
20.	A-181 × C-9	—	—	—	—	—	1.5c	1.3a	1.4b	93.3

Explanations as in Table 1.

Table 5

Mean values ($\bar{x}$) and heterosis effect of dry skin thickness (μ)

No.	Hybrid formula	1977					1978			
		$\bar{x}$				heterosis effect	$\bar{x}$			heterosis effect
		line A	line C	F_1	F_2	H according to P_{max}	linea A	line C	F_1	H according to P_{max}
1.	A-6 × C-177a	0.2a	0.6c	0,5b	0.5b	83.3	—	—	—	—
2.	A-16 × C-177a	0.3a	0.6c	0.4b	0.4b	66.7	0.3a	0.6b	0.3a	50.0
3.	A-54 × C-177a	0.3a	0.6d	0.4b	0.5c	66.7	0.2a	0.6c	0.3b	50.0
4.	A-58 × C-177a	0.3a	0.6c	0.4b	—	66.7	—	—	—	—
5.	A-125 × C-177a	0.3a	0.6c	0.3a	0.4b	50.0	0.3a	0.6c	0.4b	66.7
6.	A-19 × C-177a	0.5a	0.6b	0.7c	—	116.7	—	—	—	—
7.	A-181 × C-177a	0.4a	0.6b	0.6b	—	100.0	0.4a	0.6b	0.6b	100.0
8.	A-63 × C-177a	0.4a	0.5b	0.5b	0.4a	100.0	—	—	—	—
9.	A-16 × C-141	0.3a	0.5b	0.3a	0.5b	60.0	—	—	—	—
10.	A-58 × C-141	0.3a	0.5c	0.4b	—	80.0	0.2a	0.6c	0.3b	50.0
11.	A-12 × C-141	—	—	—	—	—	0.6b	0.6b	0.4a	66.7
12.	A-125 × C-181	0.3a	0.4b	0.5c	0.4b	125.0	0.3a	0.4b	0.4b	100.0
13.	A-181 × C-181	—	—	—	—	—	0.4a	0.4a	0.4a	100.0
14.	A-16 × C-16	0.3a	0.6c	0.3a	0.4b	50.0	0.3a	0.5b	0.3a	60.0
15.	A-6 × C-6	0.2a	0.4c	0.3b	0.4a	75.0	—	—	—	—
16.	A-125 × C-199	0.3a	0.7c	0.4b	0.4b	57.1	—	—	—	—
17.	A-19 × C-19	0.5c	0.4b	0.3a	0.4b	75.0	—	—	—	—
18.	A-16 × C-9	—	—	—	—	—	0.3a	0.5b	0.3a	60.0
19.	A-101 × C-9	—	—	—	—	—	0.4a	0 5b	0.4a	80.0
20.	A-181 × C-9	—	—	—	—	—	0.4b	0.5c	0.3a	60.0

Explanations as in Table 1.

Table 6

Mean values (x) and heterosis effect of onion bulb firmness (aacording to durometer readings)

No.	Hybrid formula	1977					1978			
		$\bar{x}$				heterosis effect	$\bar{x}$			heterosis effect
		line A	line C	F_1	F_2	H according to P_{max}	line A	line C	F_1	H according to P_{max}
1.	A-6 × C-177a	78a	84c	83c	80b	98.8	—	—	—	—
2.	A-16 × C-177a	80a	84c	84c	82b	100.0	77a	81b	81b	100.0
3.	A-54 × C-177a	79a	84b	83c	78a	98.8	76a	81b	80b	98.8
4.	A-58 × C-177a	76a	84c	79b	—	94.0	—	—	—	—
5.	A-125 × C-177a	79a	84b	83b	80a	98.9	79b	81c	68a	83.9
6.	A-19 × C-177a	81a	84b	85b	—	101.2	—	—	—	—
7.	A-181 × C-177a	78a	84b	83b	—	98.8	82b	81b	77a	93.9
8.	A-63 × C-177b	84c	82b	82b	79a	100.0	—	—	—	—
9.	A-16 × C-141	80a	80a	79a	82b	98.7	—	—	—	—
10.	A-58 × C-141	76a	80b	81b	—	101.2	75a	78b	80c	102.6
11.	A-12 × C-141	—	—	—	—	—	80b	78a	78a	97.5
12.	A-125 × C-181	79a	82b	84b	80a	102.4	79b	76a	81c	102.5
13.	A-181 × C-181	—	—	—	—	—	82b	76a	76a	92.7
14.	A-16 × C-16	80b	81b	81b	78a	100.0	77ab	78b	76a	97.4
15.	A-6 × C-6	78a	80b	83c	80b	103.7	—	—	—	—
16.	A-125 × C-199	79a	85c	84c	82b	98.8	—	—	—	—
17.	A-19 × C-19	81b	80ab	85c	79a	106.2	—	—	—	—
18.	A-16 × C-9	—	—	—	—	—	77a	80b	78a	97.5
19.	A-101 × C-9	—	—	—	—	—	72a	80b	75a	93.7
20.	A-181 × C-9	—	—	—	—	—	82c	80b	76a	92.7

Explanations as in Table 1.

Table 7

Mean values ($\bar{x}$) and heterosis effect of onion root disc diameter (cm)

No.	Hybrid formula	1977					1978			
		$\bar{x}$				heterosis effect	$\bar{x}$			heterosis effect
		line A	line C	F_1	F_2	H according to P_{max}	line A	line C	F_1	H according to P_{max}
1.	A-6 × C-177a	1.5c	1.3b	1.3b	1.2a	86.7	—	—	—	—
2.	A-16 × C-177a	1.4c	1.3b	1.4c	1.2a	100.0	1.4b	1.2a	1.4b	100.0
3.	A-54 × C-177a	1.5c	1.3b	1.3b	1.1a	86.7	1.3b	1.2a	1.3b	100.0
4.	A-58 × C-177a	1.5c	1.3a	1.4b	—	93.3	—	—	—	—
5.	A-125 × C-177a	1.4c	1.3b	1.4c	1.2a	100.0	1.1a	1.2b	1.1a	91.7
6.	A-19 × C-177a	1.4b	1.3a	1.3a	—	92.8	—	—	—	—
7.	A-181 × C-177a	1.4b	1.3a	1.3a	—	92.8	1.3c	1.2b	1.1a	84.6
8.	A-63 × C-177b	1.4b	1.3a	1.3a	1.3a	92.8	—	—	—	—
9.	A-16 × C-141	1.4c	1.2a	1.3b	1.4c	92.8	—	—	—	—
10.	A-58 × C-141	1.5c	1.2a	1.3b	—	86.7	1.3c	1.1a	1.2b	92.3
11.	A-12 × C-141	—	—	—	—	—	1.1a	1.1a	1.3b	118.2
12.	A-125 × C-181	1.4c	1.3b	1.3b	1.2a	92.8	1.1a	1.2b	1.4c	116.7
13.	A-181 × C-181	—	—	—	—	—	1.3b	1.2a	1.3b	100.0
14.	A-16 × C-16	1.4a	1.4a	1.4a	1.4a	100.0	1.4c	1.1a	1.2b	85.7
15.	A-6 × C-6	1.5c	1.2a	1.4b	1.4b	93.3	—	—	—	—
16.	A-125 × C-199	1.4b	1.4b	1.3a	1.4b	92.8	—	—	—	—
17.	A-19 × C-19	1.4b	1.3a	1.3a	1.3a	92.8	—	—	—	—
18.	A-16 × C-9	—	—	—	—	—	1.4c	1.1a	1.3b	92.8
19.	A-101 × C-9	—	—	—	—	—	1.3b	1.1a	1.1a	84.6
20.	A-181 × C-9	—	—	—	—	—	1.3b	1.1a	1.3b	100.0

Explanations as in Table 1.

Table 8

Mean value ($\bar{x}$) and heterosis effect of dry matter and sugar contents of onion

No.	Hybrid formula	Mean value ($\bar{x}$)												Heterosis effect			
		line A				line C				F_1				dry matter		sugar	
		dry matter		sugar		dry matter		sugar		dry matter		sugar		by drying	by refractometer	monosaccharides	total
		by drying	by refractometer	monosaccharides	total	by drying	by refractometer	monosaccharides	total	by drying	by refractometr	monosaccharides	total	H according to P_{max}			
1.	A-6 × C-177a	11.6	9.6	4.4	8.7	16.5	14.0	4.0	11.0	15.3	14.8	3.7	11.6	92.8	105.7	83.1	105.8
2.	A-16 × C-177a	11.6	10.2	5.1	8.1	16.5	14.0	4.0	11.0	13.6	13.0	4.3	10.7	82.6	92.8	84.2	97.6
3.	A-54 × C-177a	11.1	10.5	4.8	8.3	16.5	14.0	4.0	11.0	14.7	13.7	4.6	10.8	88.9	97.8	96.0	98.5
4.	A-58 × C-177a	11.6	10.9	4.7	8.7	16.5	14.0	4.0	11.0	13.8	12.1	4 2	9.2	83.9	86.4	90.2	83.3
5.	A-125 × C-177a	12.4	10.9	4.5	8.5	16.5	14.0	4.0	11.0	14.4	13.0	4.1	10.1	87.3	92.8	91.9	91.9
6.	A-19 × C-177a	11.3	9.6	4.1	6.7	16.5	14.0	4.0	11.0	13.4	12.5	4.6	10.1	80.9	89.3	100.9	91.9
7.	A-181 × C-177a	10.3	9.8	4.2	8.0	16.5	14.0	4.0	11.0	14.5	13.0	4.4	9.4	88.1	92.8	103.1	85.8
8.	A-63 × C-177b	15.2	12.8	2.4	9.2	15.1	12.2	3.7	11.8	15.2	13.4	3.8	10.7	100.1	104.7	102.4	90.9
9.	A-16 × C-141	11.6	10.2	5.1	8.1	13.2	11.4	3.6	8.9	12.1	11.0	4.3	8.8	91.6	96.5	84.8	98.7
10.	A-58 × C-141	11.6	10.9	4.7	8.7	13 2	11.4	3.6	8.9	11.9	10.7	3.6	8.2	90.3	93.8	76.2	92.3
11.	A-125 × C-181	12.4	10.9	4.5	8.5	11.0	9.8	3.7	7.1	11.4	10.9	3.8	7.0	92.5	100.0	84.5	82.3
12.	A-16 × C-16	11.6	10.2	5.1	8.1	9.9	8.0	3.9	6.7	11.4	10.0	4.1	7.9	98.0	98.0	80.9	97.4
13.	A-6 × C-6	11.6	9.6	4.4	8.7	14.5	12.9	3.7	10.0	14.5	14.0	3.6	11.0	100.5	108.5	79.0	110.5
14.	A-125 × C-199	12.4	10.9	4.5	8.5	16.4	15.0	4.2	10.8	15.1	14.1	4.8	10.0	92.1	94.0	107.4	91.9
15.	A-19 × C-19	11.2	9.9	4.2	7.3	11.4	10.6	4.7	8.1	12.6	10.9	3.5	7.9	110.1	102.8	75.1	97.4

Critical value of test X_2: ($a = 0.05$) = 9.46.

results signalize the possibility of selecting individuals with better bulb firmness from the F_2 generation.

The root disc diameter was significantly smaller in F_1 hybrids (Table 7), which is a very desirable phenomenon from the point of view of bulb quality.

The average dry matter and sugar contents were highest in lines C-177a, C-177b and C-141 (13-16%) (Table 8). Whereas, in the remaining A and C lines, these contents were lower and amounted from 9 to 11%. The dry matter and sugar contents in F_1 hybrids were intermediate between the parental forms. No evident heterosis was found, then, in most of the hybrids of the weight and sugar contents with the exception of F_2 hybrids (A-19×C-19) and (A-6×C-6). In addition to this, it was found that the parental lines and F_1 hybrids which were characterized by a high dry matter content also showed a higher sugar content.

DISCUSSION

One-half of the studied F_1 hybrids exhibited heterosis of bulb weight and diameter (30-50%). These differences were significant at the $\alpha = 0.05$ level. The large heterosis effect on these two traits with a high commercial significance also points to a high combining ability. This was not, however, studied in this experiment, because it had been the object of earlier investigations by this author (Doruchowski, 1968).

In order to improve other bulb characteristics (dry skin thickness, bulb firmness, dry matter content) of F_1 hybrids, a large number of lines are necessary and parental components having the desired traits should be chosen.

The heterosis of such quantitative traits as bulb weight and diameter is undisputable proof for heterosis of quantitative traits. Brewbaker (1965) thinks that these types of problems are the subject of much interest of researchers engaged in quantitative and population genetics because this hypothesis is sometimes unduly disputed by some geneticists (Kuŝmier, 1973).

The results obtained by this author in the study presented here are in agreement with the results of El-Shafie and Ahmed (1977), who believe that the heterosis of onion bulb weight may be high. The results of studies by Jones and Clarke (1943, 1943-1947), Jones and Davis (1944), Erickson and Gebelman (1954), Kobabe (1958) and Feltz (1975) have also shown that it is possible to obtain heterosis of weight. In F_1 hybrids, a higher percentage of bulbs with diameters exceeding 4 cm was found. The hybrids were characterized by good uniformity of bulb traits (e.g. size, shape, bulb color etc. Kubik, 1975-1982), and some of them were well suited for mechanical harvest and sorting as well as for storage (Sypień et al., 1978).

The weight of most of the F_2 hybrid bulbs fell significantly. These results support the widely held opinion that F_1 hybrids can only be used once, since heterosis and uniformity of bulb characteristics is found mainly in F_1. This is also indicated by the mean values and high variability of the remaining traits in F_2. The fall in the commercial value of hybrids was due to the segregation of characteristics in F_2. The onion bulbs of F_2 were very uneven in respect to almost all of the studied traits. The mean bulb weights in F_1 and F_2 (A-16×C-141) were very similar. No significant differences between them were found at the significance level of 0.05. Segregation of traits in F_2 was not observed in that hybrid. It may seem as if this trait of F_1 was fixed in F_2 and passed down from generation to generation, against Mendel's laws. Most probably, the large number of cumulative genes by which the parental forms differed were responsible. That is why there was no segregation in F_2 because the intermediate forms in this generation were more numerous than the rare forms identical with the extremely differing parental forms. The individuals which surpass the parental forms in bulb weight, dry skin thickness, bulb firmness and dry matter may become the basis on which new varieties having better bulb characteristic than both of the parental forms can be developed.

The analysis of dry matter and sugar contents in the bulbs showed that analysis of dry matter by the drying method is more exact. The content of dry matter assayed this way was slightly higher than when it was determined refractometrically. However, the refractometric method is quicker and allows differences in the dry matter contents of the studied material to be determined quickly. It is also recommended by the IBPGR *Allium* (International Board for Plant Genetic Resources) (Astley et al., 1982) working within the framework of the FAO Genetic Resources Committee and by Nieuwhof et al. (1973).

Whole onions were used for analysis of their chemical composition in order to avoid mistakes in quantitative analysis; Nieuwhof et al. (1973) found that the dry matter content of the external, fleshy parts was lower than in whole onions.

CONCLUSIONS

1. Significantly high heterosis of bulb weight, diameter and uniformity of bulb characteristics in F_1 were found. Heterosis of dry skin thickness, bulb firmness and dry matter content was significant.

2. The significant fall in bulb weight and worsening of uniformity of other traits in most of the F_2 generations confirmed the widely held view that F_1 hybrids should be used only once because trait segregation and lack of heterosis were found in F_2.

3. The lack of differences in mean bulb weights in F_1 and F_2 hybrids (A-16×C-141) and significant surpassing of parental values indicates the probability that a large number of cumulative genes, by which the parental forms differed, were active.

4. The individuals surpassing their parental forms in bulb weight, dry skin thickness, bulb firmness and dry matter content in F_2 may constitute the basis of developing new varieties with better utilitarian traits than both of the parental forms used for the cross.

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Efekt heterozji niektórych cech użytkowych cebuli (*Allium cepa* L.)

Streszczenie

Badania na temat efektu heterozji niektórych cech użytkowych cebuli przeprowadzono w Zakładzie Hodowli i Genetyki Instytutu Warzywnictwa w Skierniewicach w latach 1977 i 1978. Przebadano 15 mieszańców F_1, 11 pokoleń F_2, 16 form rodzicielskich (8 linii męskosterylnych A i 8 linii wsobnych C).

Stwierdzono wysoki efekt heterozji masy, wysokości i średnicy. Heterozja twardości cebul, przylegania suchej łuski i zawartości cukrów była nieznaczna Heterozja pozostałych cech (grubość szyjki, grubość piętki) była niska.