The Libyan Journal of Agriculture: volume 6, part 1, 1977

Inheritance of Some Characters in Cucumber, *Cucumis sativus* L.

II. Some Quantitative Characters

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ABSTRACT

The mode of inheritance of eleven quantitative characters was studied. The long cotyledonary leaf was completely dominant over the short one. A minimum of 2–3 pairs of genes seemed to control this character. The heritability of this character was 60.84%. With regard to width of the cotyledonary leaf, the F_1 exceeded the large parent indicating a case of heterosis. The minimum number of genes was one pair and the heritability was 56.46%. A case of overdominance was noted in cotyledonary leaf shape where the F_1 mean was less than the small parent. The minimum number of genes was one pair and the heritability 61.10%. The surface area of the cotyledonary leaf also showed overdominance of the parent with large area. One or two pairs of genes seemed to be involved and heritability was 61.36%.

Weight of the mature fruit showed partial dominance of the light fruit. The minimum number of genes was 3–4 pairs and heritability was 44.18%. The short fruit was dominant over the long one. Five pairs of genes seemed to be controlling this character and the heritability was 54.51%. The smaller diameter of the fruit was partially dominant over the large one with about 4 pairs of genes as might be controlling that character. A low value of heritability was obtained (15.34%) indicating that environmental factors had more effect on this character than genetic factors. The low shape index of the fruit (long-slender) was completely dominant over the high index. One pair of genes was estimated as the minimum number of genes controlling this character. Heritability was 59.22%. Diameter of seed cavity in the mature fruit showed partial dominance of the narrow seed cavity. About 3–4 pairs of genes were controlling this character. Heritability was 28.65%. No high correlation could be detected between cotyledonary leaf characters and fruit characters. On the other hand high positive correlation coefficients were obtained between the length and the diameter of mature fruit, and between the diameter of mature fruit and the diameter of seed cavity in the mature fruit.

INTRODUCTION

In a previous part of this series, the inheritance of two qualitative characters, powdery mildew and immature fruit mottling, was studied (3). The present part involves

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the study of the inheritance of quantitive characters related to seedling and fruit characteristics and earliness of flowering.

Knowledge of the inheritance of cotyledonary leaf characters, and the linkage between them and fruit characters would be helpful to cucumber breeders since they can be identified at seedling stage (13).

The shape and appearance of the cucumber fruit, and consequently its acceptability to the consumer, depends largely on its shape which in turn is determined by its length and diameter. The study of the inheritance of these quantitative traits seems necessary whenever breeding programs for high quality cucumbers are intended. Strong (12) suggested that the length of mature fruit in cucumber is governed by several genes which lacked dominance. Carlsson (2) showed that the long fruit was predominant in all cases and that fruit length was probably depending on several genes. More recently, Pike and Kingston (7) crossed two cucumber inbred lines with extreme differences in length and found that at least two genes with no dominance controlled this character. They also concluded that environment has influenced the length of fruit by the fact that fruit length differed on the same plant. Nishi and Kuriyama (6) found that the number of effective factors of fruit shape was one to two pairs of genes.

In worm areas where multiple cropping is practicable, early maturing varieties are desirable. One component of earliness in cucumber is time of flowering. Miller (5) used two early and two late flowering parents to study the inheritance of the time required to reach anthesis. Frequency distribution from parental, F_1, F_2 and both backcross populations suggested that dominance effects played an important role in the inheritance of that trait. Estimates of broad sense heritability for that trait were high.

MATERIALS AND METHODS

The mode of inheritance of ten characters was studied in a cross between inbred plant of the cultivar Yomaki and an inbred plant of the cultivar Poinsett. These characters were: 1) length, 2) width, 3) shape index, 4) surface area of the cotyledonary leaf, 5) surface area of the mature leaf; 6) weight, 7) length, 8) diameter, 9) shape index of the fruit, 10) diameter of the seed cavity in the mature fruit. An eleventh character, viz. earliness of flowering, measured as number of days from sowing to the opening of the first female flower was studied in a cross between an inbred plant of the cultivar Cool Green and an inbred plant of the cultivar Poinsett.

Growing the plants and breeding techniques were done as previously described (3). Cotyledonary leaf shape index was calculated by dividing the width over the length and multiplying the product by 100. The shape index of the mature fruit was calculated in a similar manner. Leaf area (for either cotyledonary or ordinary leaf) was determined by detaching the leaf and drawing the dimensions on a paper, then the leaf area was obtained by the use of a planimeter.

For the characters under investigation, several procedures were followed to reveal the type of dominance, number of effective genes, degree of heritability, simple and genetic correlation coefficients.

The nature of dominance was revealed by comparing the expected arithmetic mean with the observed mean of the F_1, F_2, $Bc.P_1$ and $Bc.P_2$ generations (11). The formulae used for the calculation of the arithmetic mean for the different populations were reported by Powers and Lyon (8) and Powers *et al.* (9). The agreement between the observed and arithmetic means of a given population indicates absence of dominance. When the observed mean of a given population lies between its arithmetic mean and the observed mean of one parent, this indicates partial dominance of this parent. Complete dominance is expected when the observed mean of the F_1 is not significantly different from the mean of one parent. When the observed F_1 mean exceeds one of the parents, this would indicate overdominance.

The degree of dominance is expressed as the ratio of the genotypic value of the heterozygote F_1 to the genotypic value of either parent. In case of allelomorphs, the relative potency of gene sets can be measured from these values (4,14). A potency value of 1 indicates complete dominance and a value of 0 indicates no dominance. Number of genes controlling the difference between parents were calculated using two different formulae, Sakai and Niles (10) and Wright formula mentioned by Nurton (1).

1. Length of cotyledonary leaf

As shown from Table 1, the length of cotyledonary leaf in the Yomaki parent was 4.25 ± 0.09 cm, while that of the Poinsett parent was 2.88 ± 0.05 cm. The difference between the two parental means was highly significant. The difference between the observed and the expected arithmetic means of F_1 population was highly significant indicating the presence of certain degree of dominance. The observed F_1 mean lied between its arithmetic mean and observed mean of the female parent (Yomaki). There was no significant difference between the F_1 mean and Yomaki mean indicating complete dominance of the long cotyledonary leaf.

When the observed means of F_2, Bc.P_1 and Bc.P_2 were compared with their respective arithmetic mean, significant differences were found between the actual and the theoretical means for each generation. This would be further proof for the dominance of the long cotyledonary leaf (Yomaki).

The potency ratio of +0.9633 also would indicate the dominance of the Yomaki parent.

The minimum number of genes controlling this character was estimated as 2–3 pairs of genes. The heritability value was 60.84% indicating that the genetic variance was greater than the environmental variance.

2. Width of the cotyledonary leaf

A highly significant difference was found between the observed (2.18 ± 0.02) and arithmetic means (1.83) of F_1 population, indicating the presence of dominance. The F_1 mean exceeded that of the higher parent indicating a case of heterosis. There was a highly significant difference between the observed and arithmetic means of F_2, while insignificant differences were found between the actual and the arithmetic means of Bc.P_1 and Bc.P_2 populations. In the F_1 and F_2 populations, the actual means were higher than the arithmetic means indicating dominance of the wide cotyledonary leaf. The value of potency was +1.7500 which indicates overdominance of the wide cotyledonary leaf. The minimum number of genes controlling this character was at least one pair. The heritability value was 56.46%.

3. Shape index of the cotyledonary leaf

The F_1 mean for this character was less than both parents indicating overdominance of the low shape index. The actual means of F_1, F_2 Bc.P_2 were less than the theoretical arithmetic means indicating the presence of either dominance of the low shape index or a heterotic trend. A potency value of −2.2917 would be a further proof for heterosis.

Table 1 Statistical constants for the quantitive characters of the cotyledonary leaf in parents, F_1, F_2 and backcross populations in the cross Yomaki pl. 7 × Poinsett 26 pl. 3.

Character	Generation	N	Observed mean $\pm s_{\bar{x}}$	Arithmetic mean	Geometric mean	Mean differences[a]	
						Obs. vs. arith.	Obs. vs. geom.
			1. Cotyledonary leaf				
Length, cm.	P_1	16	4.25 ± 0.09	—	—	—	—
	P_2	24	2.88 ± 0.05	—	—	—	—
	F_1	32	4.23 ± 0.04	3.57	3.50	0.66 **	0.73 **
	F_2	482	4.45 ± 0.02	3.90	3.85	0.55 **	0.60 **
	Bc.P_1	198	3.78 ± 0.04	4.24	4.24	0.46 **	0.46 **
	Bc.P_2	111	3.67 ± 0.05	3.55	3.49	0.12 **	0.18 **
Width, cm.	P_1	16	2.03 ± 0.04	—	—	—	—
	P_2	24	1.63 ± 0.03	—	—	—	—
	F_1	32	2.18 ± 0.02	1.83	1.81	0.35 **	0.37 **
	F_2	482	2.22 ± 0.01	2.00	1.99	0.22 **	0.23 **
	Bc.P_1	198	2.08 ± 0.02	2.10	2.10	0.02 n.s.	0.02 n.s.
	Bc.P_2	111	1.86 ± 0.02	1.90	1.88	0.04 n.s.	0.02 n.s.
Shape index %	P_1	16	54.01 ± 0.75	—	—	—	—
	P_2	24	57.76 ± 0.64	—	—	—	—
	F_1	32	51.59 ± 0.29	55.89	55.86	4.30 **	4.27 **
	F_2	282	50.30 ± 0.18	53.74	53.68	3.44 **	3.38 **
	Bc.P_1	198	55.25 ± 0.35	52.80	52.78	2.45 **	2.47 **
	Bc.P_2	111	51.47 ± 0.42	54.68	54.59	3.21 **	3.12 **

Surface area, cm^2	P_1	16	6.08 ± 0.29	—	—	—	—
	P_2	24	3.70 ± 0.16	—	—	—	—
	F_1	32	7.29 ± 0.13	4.89	4.74	2.40 **	2.55 **
	F_2	482	7.83 ± 0.06	6.09	5.88	1.74 **	1.95 **
	Bc.P_1	198	6.37 ± 0.14	6.68	6.66	0.31 *	0.29 *
	Bc.P_2	111	5.46 ± 0.14	5.50	5.19	0.04 n.s.	0.27 n.s.
			2. Mature foliage leaf				
Surface area, cm^2	P_1	14	235.2 ± 7.9	—	—	—	—
	P_2	25	185.9 ± 6.9	—	—	—	—
	F_1	31	201.4 ± 4.3	210.6	209.1	9.2 *	7.7 *
	F_2	554	200.2 ± 1.5	206.0	205.2	5.8 **	5.0 *
	Bc.P_1	230	222.4 ± 2.4	218.3	217.7	4.1 n.s.	4.7 n.s.
	Bc.P_2	162	227.0 ± 3.0	193.7	193.3	33.3 **	33.7 **

[a]Observed means of parents in all characters studied were statistically different at the 1% level.

Table 2 Statistical constants for the quantitative characters of the mature fruits in parents, F_1, F_2, and backcross progenies of the cross Yomaki pl. 7 × Poinsett 26 pl. 3.

Character	Generation	N	Observed mean $\pm s_{\bar{X}}$	Arithmetic mean	Geometric mean	Mean differences[a]	
						Obs. vs. arith.	Obs. vs. geom.
Weight, gm	P_1	16	737.0 ± 49.1	—	—	—	—
	P_2	19	139.0 ± 16.8	—	—	—	—
	F_1	19	281.1 ± 20.3	438.0	320.0	156.9 **	38.9 n.s.
	F_2	211	314.9 ± 10.0	359.5	299.8	444.6 **	15.1 n.s.
	$Bc.P_1$	110	389.5 ± 24.8	509.0	455.4	119.5 **	65.9 **
	$Bc.P_2$	54	318.0 ± 19.6	210.1	197.6	107.9 **	120.4 **
Length, cm	P_1	16	29.70 ± 0.91	—	—	—	—
	P_2	19	14.37 ± 0.39	—	—	—	—
	F_1	18	20.39 ± 0.70	22.04	22.66	1.65 *	0.27 n.s.
	F_2	211	19.52 ± 0.26	21.22	20.53	1.70 **	1.01 **
	$Bc.P_1$	110	21.48 ± 0.41	25.05	24.61	3.57 **	3.13 **
	$Bc.P_2$	54	19.06 ± 0.51	17.38	17.12	1.68 **	1.94 **
Diameter, cm.	P_1	16	6.53 ± 0.17	—	—	—	—
	P_2	19	4.18 ± 0.16	—	—	—	—
	F_1	18	4.75 ± 0.13	5.35	5.22	0.60 **	0.47 **
	F_2	211	5.35 ± 0.05	5.05	4.98	3.30 **	0.37 **
	$Bc.P_1$	110	5.47 ± 0.07	5.64	5.57	0.17	0.10 n.s.
	$Bc.P_2$	54	5.32 ± 0.09	4.47	4.46	0.85 **	0.86 **
Shape index %	P_1	16	22.13 ± 0.77	—	—	—	—
	P_2	19	28.58 ± 0.77	—	—	—	—
	F_1	18	23.50 ± 0.95	25.35	25.15	1.85 n.s.	1.65 n.s.
	F_2	200	27.75 ± 0.38	24.43	22.44	3.32 **	5.31 **
	$Bc.P_1$	110	26.24 ± 0.55	22.81	22.80	3.43 **	3.44 **
	$Bc.P_2$	54	28.00 ± 0.68	26.04	25.92	1.96	2.08 **
Seed cavity diameter, cm	P_1	16	3.86 ± 0.10	—	—	—	—
	P_2	19	2.16 ± 0.01	—	—	—	—
	F_1	18	2.27 ± 0.14	3.01	2.89	0.29 *	0.17 n.s.
	F_2	211	3.00 ± 0.04	2.86	2.80	0.14 **	0.20 **
	$Bc.P_1$	110	3.04 ± 0.05	3.29	3.24	0.25 **	0.20 **
	$Bc.P_2$	54	2.83 ± 0.07	2.44	2.42	0.39 **	0.41 **

[a] Observed means of parents in all characters were statistically different at the 1% level.

One pair of genes was estimated as the minimum number of genes controlling this character. Heritability was estimated as 61.10% indicating a major effect of the genetic variance.

4. Area of cotyledonary leaf

There was a highly significant difference between the actual versus the arithmetic means of F_1 generation which indicates some type of dominance. The F_1 mean was significantly higher than P_1 mean indicating heterosis in this character. The high and positive value of potency (+2.0264) was another evidence for heterosis. Most of the statistical constants and measurements were in agreement with the overdominance of Yomaki parent over Poinsett parent for this character.

The minimum number of genes controlling this character was about two pairs of genes. The value of heritability was 61.39%.

5. Area of the mature leaf

The comparisons between the observed versus the theoretical values of different populations of this character indicated the complete dominance of the smaller leaf area. The potency value was in agreement with the presence of dominance. One pair of genes was estimated as the minimum number of genes controlling this character. Heretability was estimated as 31.81%.

6. Weight of the mature fruit

The comparisons between the actual and the arithmetic means of the different generations gave an indication that the light fruit of Poinsett is partially dominant over the heavy fruit of Yomaki. Potency value of −0.5248 gave another proof for the incomplete dominance of the light fruit. The minimum number of genes controlling this character was estimated to be 3–4 pairs of genes. The value of heritability was 44.18% indicating that more than one half of the variation in this character is due to environmental factors.

7. Length of the mature fruit

The difference between the actual and arithmetic means of F_1 generation was significant and the actual F_1 mean lied between the arithmetic mean of the F_1 and the observed mean of the short-fruitted parent. The F_2 and Bc.P_1 actual means were less

Table 3 Statistical constants for number of days from sowing to first female flower in parents, F_1, F_2 and backcross progenies of the cross Cool Green 33 pl. 7 × Poinsett 26 pl. 1

Generation	N	Observed mean ± $s_{\bar{X}}$	Arithmetic mean	Geometric mean	Mean differences[a] Obs. vs. arith.	Obs. vs. geom.
P_1	27	59.22 ± 0.87	—	—	—	—
P_2	47	65.17 ± 0.46	—	—	—	—
F_1	16	56.06 ± 0.85	62.20	62.13	6.14 **	6.07 **
F_2	390	59.67 ± 0.26	59.13	59.00	0.54 **	0.67 **
Bc.P_1	114	56.26 ± 0.48	57.64	57.62	1.38 **	1.36 **
Bc.P_2	51	57.12 ± 0.63	60.62	60.44	3.50 **	3.32 **

[a]Observed means of parents were statistically significant at the 1% level.

than the corresponding arithmetic means. The potency value was −0.2141. These data would indicate the partial dominance of the short fruit. Carlesson (2) found that long fruit was predominant in all cases and that fruit length was probably depending on several genes. Strong (12) suggested that fruit length was governed by several genes that lacked dominance. The disagreement between these authors and the present results with regard to dominance of fruit length may be due to differences in varieties used.

8. Diameter of the mature fruit

The comparisons between the observed and the arithmetic means for each of F_1, F_2 and backcross populations indicated the partial dominance of the parent with small fruit diameter. Also the negative value of potency (0.5149) supports such conclusion. The minimum number of genes controlling this character was estimated as four pairs of genes. Heritability value was 15.34 indicating that this character was quite sensitive to environmental conditions.

9. Shape index of the mature fruit

The comparison between the actual mean of the F_1 and the actual mean of the parent with the smaller shape index of the fruit indicated the complete dominance of the low shape index. A high negative potency (−0.5739) also indicates the dominance of the low shape index. One pair of genes was estimated as the minimum number of genes controlling this character. Heritability was 59.22 indicating that environment had a relatively minor effect on this character.

10. Seed cavity diameter of the mature fruit

Comparing the means of the parents with the mean of the F_1 indicated the partial dominance of the narrow seed cavity. The value of potency (−0.3489) supports this conclusion. A minimum of 3–4 pairs of genes was estimated for this trait. A low value of heritability (28.65%) for this character was obtained.

11. Number of days from planting to the first female flower

Data of this character was obtained from the cross Cool Green 33 pl. 7 × Poinsett 26 pl. 1. The average number of days that elapsed from sowing till the appearance of the first female flower was 59.22 ± 0.87 in Cool Green, while it was 65.17 ± 0.46 days in Poinsett. The difference between the two parental means was 5.95 days and it was highly significant. A case of heterosis was recorded in this character since the F_1 mean was significantly less than the two parental means. The actual mean of the F_1 was less than the corresponding arithmetic mean indicating the presence of dominance of the early parent. Potency value of −2.0624 would indicate the dominance of the early parent. Heritability of this character was 47.67 indicating that the genetic variance was nearly equal to the environmental variance. The results obtained about this trait are in general agreement with those obtained by Miller (5).

Nature of gene action

For all the studied characters the comparisons of arithmetic and geometric means versus the observed means did not give any indication for the mode of gene action. Correlation between Characters.

Table 4 Different parameters for type of inheritance of ten quantitative characters.

Character	Potency	Skewness	Scaling			Minimum No. of genes		
			F_2	$Bc.P_1$	$Bc.P_2$	Wright	Sakai & Niles	Herit-ability
1. The cross Yomaki pl. 7 × Poinsett 26 pl. 1								
Length of cotyledonary leaf (cm)	+0.96	−0.14 n.s.	2.20 n.s.	0.91 n.s.	0.24 n.s.	2.51	1.71	60.84%
Width of cotyledonary Leaf (cm)	+1.75	−0.73**	0.89 n.s.	0.04 n.s.	0.08 n.s.	1.39	0.55	56.46%
Shape index of cotyledonary leaf (%)	−2.29	+0.18 n.s.	13.75 n.s.	4.90 n.s.	6.41 n.s.	0.14	0.13	61.10%
Area of cotyledonary leaf (cm^2)	+2.03	−0.11 n.s.	6.95 n.s.	0.63 n.s.	0.08 n.s.	1.50	0.49	61.39%
Mature leaf area (cm^2)	−0.37	+0.09 n.s.	23.39 n.s.	54.36 n.s.	66.73 n.s.	0.50	0.47	31.81%
Weight of mature fruit (gm)	−0.52	+0.55 **	178.47 n.s.	239.05 n.s.	216.01 n.s.	3.83	3.36	44.18%
Length of mature fruit (cm)	−0.21	+0.18 n.s.	6.77 n.s.	7.14 n.s.	3.36 n.s.	5.11	4.99	54.51%
Diameter of mature fruit (cm)	−0.51	+0.29 n.s.	1.18 n.s.	0.34 n.s.	1.71 n.s.	4.09	3.61	15.34%
Shape index of mature fruit (%)	−0.57	+0.38 *	13.30 n.s.	6.84 n.s.	3.92 n.s.	0.46	0.391	59.22%
Seed cavity diameter of mature fruit (cm)	−0.35	+0.72 **	0.54 n.s.	0.49 n.s.	0.78 n.s.	3.85	3.63	28.65%
2. The cross Cool Green 33 pl. 7 × Poinsett 26 pl. 1								
Number of days to first female flower		−2.06	−0.10 n.s.	2.16 n.s.	2.76 n.s.	7.00 n.s.	0.32	0.32

Table 5 Correlation coefficients for different pairs of characters studied in the cross Yomaki pl. 7 × Poinsett 26 pl. 3

Character pairs	Phenotypic r	Genetic r
Cotyledon length, cm vs. fruit length, cm	+0.149 *	+0.151 *
Cotyledon shape index vs. fruit shape index	+0.039 n.s.	+0.042 n.s.
Cotyledon area, cm^2 vs. mature leaf area, cm^2	+0.201 *	+0.115 *
Mature leaf area, cm^2 vs. fruit weight, gm.	+0.163 *	+0.168 *
Fruit length, cm vs. fruit diameter, cm.	+0.507 **	+0.509 **
Fruit diameter, cm vs. seed cavity diameter, cm.	+0.773 **	+0.768 **
Fruit length, cm vs. seed cavity diameter, cm.	+0.455 **	+0.464 **

Although a positive and significant correlation was found between length of cotyledonary leaf and fruit length, between cotyledonary leaf area and mature leaf area, and between mature leaf area and fruit weight, such correlation was quite low as shown in Table 5. The correlation between cotyledonary leaf shape index and fruit shape index was not significant. The weak association between measurements of cotyledonary leaf and measurements of the fruit would indicate that the length and fruit shape cannot be forcasted during the seedling stage through measuring cotyledonary leaf length and cotyledonary leaf shape index respectively. Accordingly, selection for certain fruit characters cannot be made during the seedling stage.

On the other hand high correlation coefficients were obtained within different characters of the fruit. High phenotypic and genetic correlation coefficient was obtained for the length of the mature fruit and the diameter of the mature fruit. High and positive values of r were also obtained between the diameter of mature fruit and the diameter of seed cavity in the mature fruit which indicates that these two characters have a high tendency to vary together. The coefficient of determination was 0.590 which indicates that 59% of the genetic variability of seed cavity diameter in the mature fruit was due to the variation in fruit diameter.

Medium values of the phenotypic and genetic correlation coefficients were found between length of mature fruit and seed cavity diameter in the mature fruit. The coefficient of determination (0.214) indicates that about 21% of the variation of seed cavity diameter could be ascribed to the effect of the mature fruit length.

The genetic correlation between characters could be due to linkage, pleiotrophic effect of genes, or effect of selection.

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