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Inheritance of Time to Flowering and its Relationship to Crop Maturity in Cucumber[1]

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Abstract. **Early and late flowering cultivars of cucumber (*Cucumis sativus* L.) and their progenies were used to determine the inheritance of the time required to reach anthesis and its importance as a component of earliness. Genetic variance was primarily additive; however, partial dominance for early flowering and low nodal position of the first flower was noted. Days to first flower appeared to be controlled by relatively few genes, and heritability estimates for this trait were moderately high (0.46 to 0.62). Number of days to flowering was found to be more important in early crop maturity than was rate of seedling emergence. Lower temperatures delayed flowering, and thus maturity, by slowing plant growth and raising the node number at which the first flower appeared. A significant correlation coefficient of 0.82 was obtained between flowering time and mean maturity date.**

Early maturity of pickling cucumber is an important factor in commercial production. The necessary equipment for mechanization is expensive, and continuous use is required to minimize costs. Efficient equipment utilization can be achieved by staggered plantings and by multiple cropping. Early maturing cultivars can reduce production costs by shortening the growing season.

Early flowering should be an important factor in crop maturity. In previous investigations with cucumber (7, 8), substantial intraspecific variability was observed for time from planting to first flower, suggesting that this trait might be under genetic control. Inheritance patterns for days to flowering in watermelon, *Citrullus vulgaris* Schrad, and muskmelon, *Cucumis melo* L., have been reported (13, 2). Shifriss and George (12) using a parental cultivar which was day neutral with respect to flowering and one which required short days for normal flowering reported that the differential photoperiodic flowering behavior of these cultivars in long days was controlled by a single recessive gene.

This investigation was undertaken to determine the inheritance of days to flowering and node of the first flower and to evaluate the importance of early flowering to early crop maturity in cucumber.

Materials and Methods

Plant material and traits measured. Two early flowering lines, EF-MSU 0612 and EF-TXL 29, and 2 late flowering lines, LF-'Poinsett' and LF-MSU 713-5, were used as parents. EF-TXL 29 was derived from Peto experimental hybrid 36-65, which was early flowering. LF-'Poinsett' was selected from the late flowering 'Poinsett'. No progress was made by selfing and selection for early and late flowering, respectively, in EF-MSU 0612 and LF-MSU 713-5. EF-MSU 0612 and LF-'Poinsett' are monoecious, whereas LF-MSU 713-5 and EF-TXL 29 are gynoecious. LF-MSU 713-5 initiates flowers relatively early, but flower abortion is encountered at the first few nodes, resulting in late flowering.

Selfed progeny of the 4 parental lines were crossed to develop F_1, F_2, BC_1, and BC_2 populations. Three separate families were generated: Family I (EF-TXL 29 x LF-'Poinsett'), Family II (EF-MSU 0612 x LF-'Poinsett'), and Family III (EF-MSU 0612 x LF-MSU 713-5).

Date and sex of each new flower were recorded on each entry through the 10th node. Two criteria were judged to best detect genotypic differences in flowering behavior. These were days from planting to first flower and the node at which the first flower appeared. The cotyledonary node was designated node 0, with the node at which the first true leaf appeared considered node 1.

Genetic analyses. Quantitative genetic procedures were used to analyze the data. Analyses of variance were conducted to evaluate the possibility of maternal effects. Scaling tests (6) tested the conformity of the data to the additive-dominance model. Estimates of additive, dominance, and environmental variances were obtained (6). Heterosis (measured as % deviation from the mid-parental values) and degree of dominance (estimated by dividing the square root of dominance variance by the square root of additive variance) were calculated. Narrow and broad sense heritability estimates were computed as the ratio of additive genetic variance to phenotypic variance and the

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Table 1. Population size, means, standard errors, parental range, midparent value, and heterosis for days to first flower in 3 cucumber families.

Population	Family I[z] N	Family I[z] Mean ± SE	Family II[y] N	Family II[y] Mean ± SE	Family III[x] N	Family III[x] Mean ± SE
P_1	94	36.2 ± 1.45	63	34.9 ± 1.45	81	34.6 ± 1.37
BC_1	28	37.0 ± 1.35	142	35.6 ± 1.84	70	34.1 ± 1.77
F_1	6	37.5 ± 1.91	104	36.3 ± 1.42	12	35.1 ± 1.16
F_2	91	37.7 ± 2.53	251	36.9 ± 2.56	224	35.7 ± 2.12
BC_2	44	38.1 ± 2.84	80	37.8 ± 2.59	158	36.4 ± 1.89
P_2	88	42.1 ± 1.70	56	42.6 ± 1.85	83	38.5 ± 1.67
P_1–P_2, Range		5.9		7.7		3.9
Midparent value		39.15		38.75		36.55
Heterosis[w]		4.2		6.3		4.0

[z]EF-TXL 29 x LF-Poinsett.
[y]EF-MSU 0612 x LF-Poinsett.
[x]EF-MSU 0612 x LF-MSU 713-5.
[w]Heterosis = (F_1-MP/MP) x 100.

ratio of total genetic variance to phenotypic variance, respectively.

The minimum number of effective factors (k) that controlled flowering time were determined by averaging estimates provided by the methods of Mather and Jinks (including additive variance) (6), Castle (4), Wright as reported by Burton (3), and Wright's (14) method modified to include backcross variances.

Effect of planting date. The families were evaluated twice under short day (SD) conditions (10 and 11 hr) and once under long day (LD) conditions (14 hr), with average temp of 24, 14 and 26°C. The SD studies were planted in the field and greenhouse on Sept. 9, 1973, and Jan. 21, 1974, respectively, while the LD study was planted June 4, 1974, in the field. In the greenhouse, plants were grown in 18 cm pots. Field studies were hand planted with 30 cm spacing on 102 cm rows. Twenty seed of each population were sown per block. Plots were irrigated immediately after planting and no herbicide was applied. A completely randomized block design was used.

Emergence, flowering, and maturity. The 4 parental lines and 3 additional cultivars, 'Pioneer', 'SMR 58', and 'Marketmore', were planted in the field on May 6, 1974, in a randomized block design with 3 replications. Each replication was thinned to 25 plants on 102 cm rows, with 15 cm between plants. A bee colony was introduced to insure pollination. Three traits were measured to determine their importance in early fruit maturity. The no. of days required for seedling emergence from the soil was calculated as the mean emergence date (MED) for each of the 7 entries (10). The no. of days required for 50% of the plants in each entry to reach first flower was calculated and designated F_{50}. The third trait, mean maturity date (MMD), was based on the no. of fruits that were harvested and graded at weekly intervals (5). These harvests started 57 days after planting and ended 94 days after planting. Analyses of variance and correlation analyses were used to evaluate the relationships between emergence rate, flowering time, and earliness of crop maturity.

Table 2. Estimates of components of variation, heritability, degree of dominance, and min. no. of effective factors, for no. of days from planting to first flower in 3 cucumber families.

Variable	Families I[z]	Families II[y]	Families III[x]
Environmental variance (E)	2.490	2.517	1.999
Total genetic variance (G)	3.925	4.058	2.480
Additive variance (D)	2.970	3.089	2.263
Dominance variance (H)	0.956	0.969	0.218
Heritability (h^2) for F_2			
Narrow sense	0.46	0.47	0.51
Broad sense	0.61	0.62	0.55
Degree of dominance	0.80	0.79	0.44
Effective factors (k)	1.4	1.9	1.1

[z]EF-TXL 29 x LF-Poinsett.
[y]EF-MSU 0612 x LF-Poinsett.
[w]EF-MSU 0612 x LF-MSU 713-5.

Table 3. Population size, means, standard errors, parental range, midparent value, and heterosis for node of first flower in 3 cucumber families.

Population	Node of 1st flower: Family I[z] N	Family I[z] Mean ± SE	Family II[y] N	Family II[y] Mean ± SE	Family III[x] N	Family III[x] Mean ± SE
P_1	94	1.92 ± 1.17	63	0.70 ± 0.71	81	0.77 ± 0.68
BC_1	28	1.41 ± 1.18	142	0.87 ± 0.76	70	1.00 ± 0.91
F_1	6	1.67 ± 0.82	104	0.90 ± 0.61	12	1.85 ± 0.69
F_2	91	1.19 ± 0.85	251	1.13 ± 0.84	224	1.88 ± 1.38
BC_2	44	1.31 ± 0.87	80	1.72 ± 0.85	158	2.86 ± 1.70
P_2	88	2.35 ± 0.71	56	2.32 ± 0.87	83	3.60 ± 2.05
P_1–P_2, Range		0.43		1.62		2.83
Midparent value		2.14		1.51		2.19
Heterosis[w]		22.0		40.4		15.5

[z]EF-TXL 29 x LF-Poinsett.
[y]EF-MSU 0612 x LF-Poinsett.
[x]EF-MSU 0612 x LF-MSU 713-5.
[w]Heterosis = (F_1-MP/MP) x 100.

Results

Results from the scaling test indicated that the additive-dominance model was acceptable for all crosses (all 3 families). Tests to determine the possibility of maternal effects were not statistically significant; therefore, reciprocal crosses were pooled.

Days to first flower. The F_1 means were between the parental means, but tended to be closer to the early flowering parents (Table 1). Positive heterosis values were obtained for the 3 families. The F_1 means indicated partial dominance for early flowering. With the exception of the BC_1 population in Family III, the BC_1 and BC_2 means were located between the F_1 means and those of the respective parental means.

Additive variance was greater than dominance variance in all families (Table 2). The values for degree of dominance further indicated partial dominance for early flowering. A minimum of 1 to 2 major effective factors appeared to be segregating for early flowering, depending on the cross. Estimates of both broad (0.55 to 0.62%) and narrow (0.46 to 0.51%) sense heritability were moderately high for all 3 families.

Node of first flower. Ranges of 0.43, 1.62, and 2.83 in nodal position of the first flower were observed between the early and late flowering parents (Table 3). No significant differences in nodal position of the first flower were observed for parents used more than once to make up the 3 families.

Means of the segregating populations in Family I were not expected (i.e., they were lower than either of the parents). Variance components further showed that it was not possible to identify a genetic system for this character in Family I, and differences were assumed to be entirely due to environment (Table 4).

Heterosis values for Families II and III were estimated to be 40.4 and 15.5, respectively. Estimated variance components for Families II and III showed that the environmental variance greatly exceeded the total genetic variance. Environment appeared to play the predominant role in determining nodal position of the first flower in cucumber. Additive variance was slightly larger than the dominance variance. Narrow and broad

Table 4. Estimates of components of variation, heritability, degree of dominance, and min no. of effective factors for node of first flower in 3 cucumber families.

Variable	Families I[z]	II[y]	III[x]
Environmental variance (E)	0.919	0.524	1.715
Total genetic variance (G)	0.000	0.185	0.201
Additive variance (D)	0.000	0.121	0.114
Dominance variance (H)	0.000	0.064	0.087
Heritability (h^2) for F_2			
Narrow sense	–	0.17	0.06
Broad sense	–	0.26	0.11
Degree of dominance	–	1.03	1.24
Effective factors (k)	–	1.5	3.3

[z]EF-TXL 29 x LF-Poinsett.

[y]EF-MSU 0612 x LF-Poinsett.

[x]EF-MSU 0612 x LF-MSU 713-5.

Table 5. Environmental conditions during summer, fall, and winter greenhouse plantings of 3 cucumber families.

Planting	Photoperiod (hr)	Avg temp (°C) Maximum	Mean	Minimum
Summer (field)	14	34	26	19
Fall (field)	11	22	14	6
Winter (greenhouse)	10	29	24	18

sense heritability estimates were low. Estimates of the minimum major factors that segregated for node of first flower were higher than those values obtained for days to first flower.

Effect of planting date. Regardless of planting date, results from the genetic analyses were similar, thus only the summer planting data are presented. However, useful information was obtained on the influence of photoperiod and temp on the 3 traits (Tables 5 and 6).

Significant differences were observed in days to first flower for the 3 families (mean values of P_1, P_2 and F_1 data) when grown in the field and greenhouse (Table 6). Fewer days to flowering were required under the winter greenhouse, followed by summer and fall conditions, respectively. The relatively low temp encountered in the fall (Table 5) substantially slowed growth and therefore extended the time to first flower. The differences observed between flowering time under summer field and winter greenhouse conditions could have resulted from the more uniform conditions encountered in the greenhouse. All 3 families responded similarly to the 3 environments, suggesting a minimum genotype by environment interaction.

Temp apparently played a significant role in determining the node no. at which the first flower appeared. The average node at which the first flower appeared under fall conditions was 2.7, whereas it was 1.3 and 1.8 under winter greenhouse and summer conditions, respectively. Therefore, lower temp may have delayed flowering by slowing plant growth and by causing pre-anthesis flower abortion. This was especially true of LF-MSU 713-5 which is very prone to flower abortion at lower nodes (Table 6).

Emergence, flowering and maturity. Significant differences were obtained among the lines tested for MED, F_{50}, and MMD (Table 7). Days to flowering was more important to early crop maturity than was rate of seedling emergence. Although significant differences in MED were observed among the lines tested, only a 2.6 day range was observed. This range was probably not large enough to make an appreciable difference in days to maturity. Furthermore, a nonsignificant correlation coefficient

Table 6. Effect of planting date on days to first flower and node of the first flower in 3 cucumber families.

Family	Plantings: Summer field	Fall field	Winter greenhouse	Avg
	Days to 1st flower			
I	38.6	51.6	34.5	41.5a[z]
II	37.9	51.6	33.5	41.0a
III	36.1	51.0	31.9	39.6a
Avg	37.5b	51.4a	33.3c	
	Node of 1st flower			
I	2.0	2.6	1.7	2.1a
II	1.3	2.3	1.0	1.5a
III	2.1	3.4	1.2	2.2a
Avg	1.8b	2.7a	1.3b	

[z]Mean separation within columns or rows by Duncan's multiple range test, 5% level.

Table 7. Mean emergence date (MED), mean F_{50}[z] and mean maturity date (MMD) values for 7 cucumber cultivars or lines.

Cultivar or line	MED (days)	F_{50} (days)	MMD (days)
EF-MSU 0612	9.2cd[y]	37a	75.3ab
EF-TXL 29	7.5a	38a	73.9a
Pioneer	7.3a	41b	77.1bc
SMR 58	7.2a	45c	77.6bc
LF-Poinsett	7.7ab	47d	81.2de
Marketmore	9.8d	47d	83.4e
LF-MSU 713-5	8.5bc	48d	79.6cd
Average	8.2	43	78.3

[z]F_{50} = No. of days from planting, required for 50% of the plants in each entry to reach anthesis.

[y]Mean separation within columns by Duncan's multiple range test, 5% level.

(0.44) was obtained between MED and MMD. Early flowering lines produced most of their fruits earlier than did late flowering lines. A significant correlation coefficient 0.82 was obtained between F_{50} and MMD.

Discussion

The same genetic system, regardless of sex type, is probably involved in early flower initiation. Cucumber flowers pass through a bisexual stage then develop into pistillate, staminate, or perfect flowers (1). Thus, time of flowering is not necessarily associated with sex expression. For example, Family III (EF-MSU 0612 x LF-MSU 713-5) involved an early flowering monoecious line and a late flowering gynoecious line. To determine if early flowering was associated with the gynoecious trait, a correlation was conducted between mean flower days (mean no. of days required from planting to the appearance of the first 10 flowers) and female ratio (ratio of pistillate to staminate flowers in the first 10 flowers). A nonsignificant correlation coefficient of 0.005 suggested that no such relationship existed in this population. Thus, an early flowering monoecious plant can produce fruit earlier than a late flowering gynoecious or a predominantly female plant.

In monoecious cultivars, early production of pistillate flowers is important for early maturity; however, the significance of early staminate flower production should not be overlooked. A monoecious cucumber plant possesses potentiality for a floral developmental sequence consisting of staminate flowers on the lower nodes, followed by a mixed phase (monoecious), then a pistillate phase (9, 11). Monoecious cultivars can differ in the no. of nodes to the first pistillate

flower on the main stem. Shifriss and Galun (11) have stated that the no. of nodes to the first pistillate flower is a reasonably good measure of both sex tendency and maturity. Therefore, early staminate flowering is a prerequisite for early expression of the subsequent mixed and pistillate phases, and thus early maturity in monoecious cultivars.

The significant additive genetic variance for early flowering in cucumber suggests that selection should be effective for either monoecious or gynoecious cultivars. Early flowering was shown to be an important component of early crop maturity. The no. of days to flowering was controlled by a rather simple genetic system, and estimates of heritability were moderately high. Node of the first flower had low estimates of heritability and was strongly influenced by the environment. Since flowering time in the F_1 populations closely approximated the early flowering parent, dominace could be beneficial in the development of new hybrid combinations.

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Relation between Growth of Chrysanthemums and Aeration of Various Container Media[1]

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Abstract. Chrysanthemum morifolium **cv. Brilliant Anne was grown in 13 different media under frequent irrigation such that all media were nominally at container capacity. Media were selected to represent a range in air-filled porosity (0–20%) at container capacity with a depth of 12 cm. Substantial addition of organic amendment (40–90% v/v) improved aeration in a poorly aggregated loam and in two sands. Peat plus vermiculite had the best aeration of all media. Thirty day top yields were related to aeration properties of the media measured at container capacity. A value of 10–15% air-filled porosity was generally related to best growth. Oxygen diffusion rate (ODR) for the medium profile provided a better correlation with plant growth than air-filled porosity. A profile ODR of 45g $O_2 \times 10^{-8}$ cm^{-2} min^{-1} and above gave best growth.**

Following irrigation and drainage a container medium is more or less aerated depending on its pore size distribution and depth. A zone of saturation forms at the bottom of the profile and extends upward, its height depending on the moisture characteristic of the medium (15). An excellent field soil often performs poorly as a container soil since it may contain few air-filled pores at container capacity. At least one objective in amending container soils is to create a medium with significant numbers of large pores which are air-filled after irrigation.

Aeration of container media is considered important, yet there have few attempts (6, 7, 10, 12) to quantify aeration status of these media. Where frequent irrigation is desirable (1, 14) container plants must be grown in well aerated media to sustain healthy roots and good top growth. If media are not well aerated frequent irrigation sometimes leads to decreased growth (2). Besides frequent irrigation, circumstances where aeration is apt to be limiting are: following transplanting of cuttings, during low evaporative conditions, with over potted plants, and immediately following irrigation. In shallow containers it is possible that portions of the root system are without aeration following irrigation, and until transpiration creates sufficient aeration, plant roots may be damaged (5, 8). While well aerated container media are sought, a measure of aeration related to plant growth is also needed to evaluate the suitability of such media. The purpose of this paper was to examine the relationship between growth of chrysanthemum and soil aeration using various media under frequent irrigation conditions. Air-filled porosity and oxygen diffusion rate (ODR) were used to measure soil aeration.

Materials and Methods

Thirteen media were selected such that at container capacity they represented a wide range of air-filled porosities (Table 1). Sands and soils were amended with ½ sphagnum peat and ½ redwood sawdust added on a v/v basis. The peat vermiculite mixture consisted of (v/v basis) ½ sphagnum peat and ½ vermiculite (No. 2 grade). VAMA (vinyl acetate maleic anhydride)

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